ADVENTURES IN TRACKING ONLINE ANONYMITY

MIT Technology Review

VOL. 118 NO. 1 JANUARY/FEBRUARY 2015 $6.99

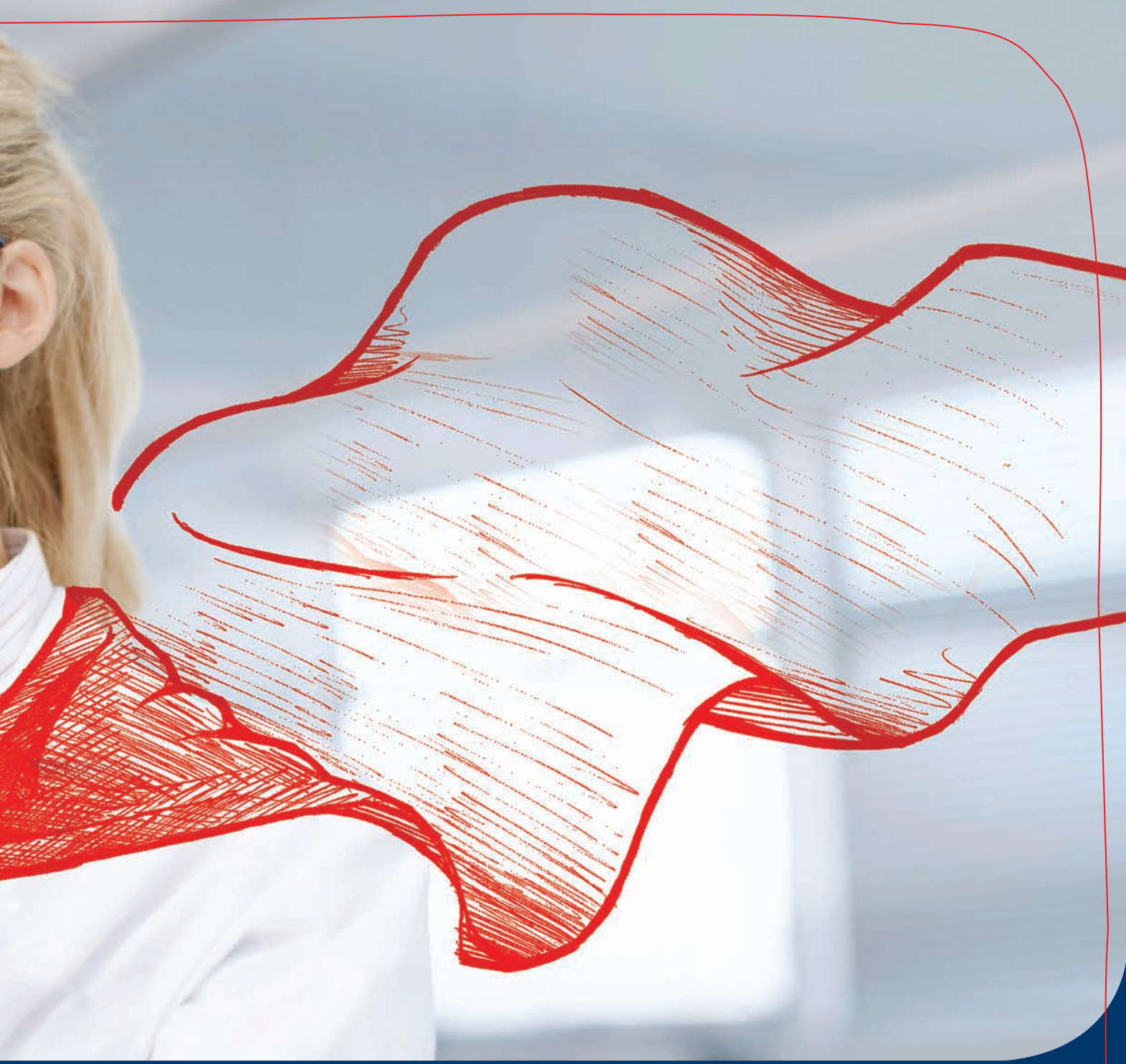
troll hunters

page 50

0 09281 01308 2

Biotech is more than just a job. It's a mission to feed, fuel and heal the world. And there's no better place to connect with biopharma's top people and most innovative technologies than at BIO 2015 in Philadelphia, June 15 - 18. The ideas and information shared at BIO go beyond professional development. You'll experience powerful business partnering, benefit from invaluable education sessions and have the chance to network with 15,000 of the industry's best and brightest from 65 countries around the world.

Learn more at convention.bio.org #BIO2015



SUPERcharge your BIO experience.

BIO International Convention

The Global Event for Biotechnology

June 15–18, 2015
Philadelphia Convention Center
Philadelphia, PA

convention.bio.org

From the Editor

GUIDO VITTI

IN "THE TROLL HUNTERS" (PAGE 50), Adrian Chen writes, "Old-school hate is having a sort of renaissance online, and in the countries thought to be furthest beyond it. The anonymity provided by the Internet fosters communities where people can feed on each other's hate."

Chen reveals the scale of *näthat* ("Net hate") in Sweden, a country known for its tolerance, where anonymous posters to websites nonetheless rage against immigrants who (racists believe) are destroying "Swedish culture." As in the United States and elsewhere in the world, Internet trolls in Sweden also persecute women, often just for the strange satisfaction of frightening them.

Trolls must be moved by bitter resentments they cannot otherwise express and liberated by the heady unaccountability of anonymity. Harassing comments found on websites are sincere expressions of how a portion of humanity really feels. Some people hate other people, and technology amplifies the expression of views that (at least since the end of World War II) were mostly whispered in private or shouted at rallies of ineffectual political movements (see "Free Speech in the Era of Its Technological Amplification," March/April 2013). But what can be done about trolling in open societies like Sweden and the United States is a vexed question about which citizens ardently disagree.

Both the United States and Sweden have set high bars for criminalizing speech: speech is presumptively free unless it violates the "harm principle." In America, speech can be banned if it is a "real threat," either because it constitutes an incitement to hurt someone or (as Justice Sandra Day O'Connor wrote in 2003) to protect people "from the fear of violence" and "from the disruption that fear engenders." Citizens who value free speech and believe it necessary for democracy, individual expression, and a marketplace of ideas are mostly comfortable with such a limited constraint.

But others are not so comfortable (see "Q&A: Shanley Kane," page 26). Threats are seldom prosecuted, because words are slippery things and anonymous trolls cannot be found easily. More, the harm principle is not simply extended to harassing speech that seeks to oppress or silence minorities and women. Activists would like to see a wider legal definition of harm, or broader intolerance for harassment.

Chen's feature describes one controversial approach in Sweden, where "a group of volunteer researchers called *Researchgruppen*, or Research Group, has pioneered a form of activist journalism based on following the crumbs of data anonymous Internet trolls leave behind and unmasking them." Research Group scraped the comments of a right-wing publication named Avpixlat, and matched the encrypted e-mail addresses of commenters against a database of publicly available addresses. The researchers gave the names of many of Avpixlat's most prolific commenters to *Expressen*, a Swedish tabloid, which then reported that dozens of prominent Swedes, including politicians from the far-right Sweden Democrats, had posted racist and sexist comments. Some politicians and officials resigned.

Research Group's public shaming of trolls was controversial in Sweden. *MIT Technology Review* readers may also feel troubled: they might want to distinguish between real threats to individuals and the expression of views that, however reprehensible, have a tenuous connection to immediate harm. But the data journalists of Research Group were responsible for an innovation: they put a cost to trolling. By stripping away the cloak of anonymity, they demonstrated that while speech is free, it is not always without consequences.

Contents

Front

2 **From the Editor**

8 **Feedback**

VIEWS

10 **MOOCs' Teachable Moment**
How online education can help erase the skills gap.

10 **Fixing Autism Research**
For starters, we can stop searching for a "cure."

11 **The World Needs Anonymity**
It's not always a bad idea to keep your identity to yourself.

12 **On Creativity**
A newly unearthed, previously unpublished essay by science fiction great Isaac Asimov.

UPFRONT

15 **An End-Around for Consumer Genetics**
The FDA has stymied 23andMe, but tests live on.

20 **The Mystery of Autism**
One problem: nobody agrees on how to diagnose it.

21 **Voice Recognition for the Internet of Things**
Getting your thermostat to recognize your voice.

22 **Ultrasound Gets Small**
How a new chip could upend diagnostics.

24 **Will a Breakthrough Solar Technology See Daylight?**
A startup's record-breaking cells meet economic reality.

Q+A

26 **Shanley Kane**
Is Silicon Valley hopelessly sexist?

Can coal be clean?
p. 84

January/February 2015

28 | **Can Japan Recapture Its Solar Power?**
A lesson in the political vulnerability of renewable energy. *By Peter Fairley*

36 | **Solving the Autism Puzzle**
A new approach to finding the genes behind autism shows promise. *By Stephen S. Hall*

44 | **Desalination out of Desperation**
Severe droughts are making researchers rethink how we can get fresh water. *By David Talbot*

50 | **The Troll Hunters**
Exposing thugs, bullies, and racists on the Internet seems like a good thing. Can it go too far? *By Adrian Chen*

Back

BUSINESS REPORT

59 **Cities Get Smarter**
How technology can make urban centers more efficient, better places to live.

REVIEWS

68 **Do MOOCs Actually Work?**
College survived. But online courses are still worthwhile. *By Justin Pope*

72 **The Aura Apps**
Do digital filters change the meaning of the "past"? *By A. D. Coleman*

79 **Google Glass Is Dead**
This wearable computer isn't a hit, but the vision lives on. *By Rachel Metz*

DEMO

84 **Coal Plant Buries Its Own Greenhouse Gases**
Showing that carbon sequestration can be done. *By Peter Fairley*

45 YEARS AGO

88 **Education by Machine**
When the teacher is a computer, learning can get personalized.

ON THE COVER

Illustration by R. Sikoryak based on Tintin in Tibet, *by Hergé, 1960*

PHOTOGRAPH BY JENN ACKERMAN AND TIM GRUBER

MIT Technology Review **Insider**

Discover how technology will change the world for the better. Join us.

Exclusive Content
Full access to print and digital content, including exclusive videos, interviews, features, Business Reports, and special publications.

Unique Experiences
Exclusive discount offers and opportunities, like preferred seating, speaker meet-and-greets, and private networking sessions.

Impassioned Community
The premier community of leaders and innovators who seek to understand and influence technology in the world around them.

technologyreview.com/GetInsider

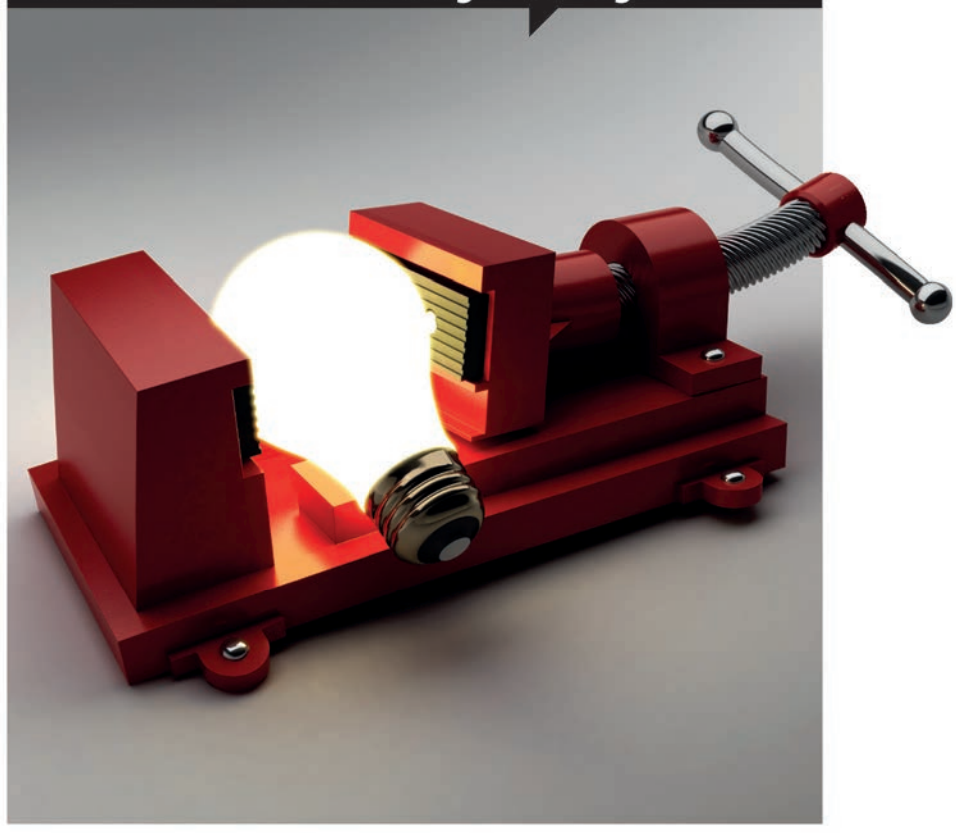
Technology Review
One Main Street, 13th Floor
Cambridge, MA 02142
Tel: 617-475-8000

The mission of *MIT Technology Review* is to equip its audiences with the intelligence to understand a world shaped by technology.

Technology Review, Inc., is an independent nonprofit 501(c)(3) corporation wholly owned by MIT; the views expressed in our publications and at our events are not always shared by the Institute.

De Technologia non multum scimus. Scimus autem, quid nobis placeat.

Are Patent Trolls Crushing Your Bright Ideas?



If predatory litigation is threatening your innovation with massive legal fees, protect your new brainstorm with the brain trust of an established Intellectual Property law firm. Since 1972 **Allen, Dyer, Doppelt, Milbrath & Gilchrist, P.A.** has protected the intrinsic rights of clients' original ideas and new technologies through the application of copyrights patents, trademarks, licensing, infringement protection,trade secrets protection and unfair competition litigation. **ADDM&G** serves local, statewide, national and international clients.

Contact **ADDM&G** today for further information. **www.addmg.com**

ADDM&G

ALLEN, DYER, DOPPELT, MILBRATH & GILCHRIST, P.A.

INTELLECTUAL PROPERTY ATTORNEYS

Listed in Intellectual Property Today as:
22ND in the nation for trademarks issued
Top 100 in the nation for patents issued

2012 2013 BEST LAW FIRMS U.S.News Best Lawyers

ALLEN, DYER, DOPPELT MILBRATH & GILCHRIST, P.A.
TOP LISTED IN Best Lawyers®
THE WORLD'S PREMIER GUIDE

Orlando · 407·841·2330 | Jacksonville* · 904·398·7000 | Miami · 305·374·8303
Tampa* · 813·639·4222 | Winter Springs · 407·796·5064

GRAY MATTER MATTERS

*Satellite Office

Feedback

E-mail letters@technologyreview.com

Write *MIT Technology Review*
One Main Street, 13th Floor
Cambridge, MA 02142

Please include your address, telephone number, and e-mail address.

Letters and comments may be edited for both clarity and length.

Five Most Popular Stories

MIT Technology Review
Volume 117, Number 6

1

Technology and Inequality

MIT economist David Autor is quoted as saying we would be hard pressed to find a robot today. The self-serve gas pump, the answering machine, the word processor, the self-checkout in the grocery store, and the automated door opener are the "robots" that Autor is not seeing. Each of these devices represents an entry-level job that no longer exists.

—dennis.drew.737

2

The Right Way to Fix the Internet

Big telecom argues that their monopoly should be strengthened, which will then give them the security to make infrastructure improvements. Meanwhile, they lobby behind the scenes to make it illegal for cities to install their own fiber networks. Clearly their interests are not aligned with consumer interests. **—SneedUrn**

Net neutrality is not about fairness to corporations or startups. It is about letting users have full control over what they want to access via the Internet. **—gubrud**

3

Fun with Food

I'm by no means a foodie, but I thought Corby Kummer's article on food experimentation was one of the best I have read in *MIT Technology Review*. Ironic, though, that it comes in the context of the "Inequality" issue. Still, kudos to Denmark that it can maintain a still-generous social welfare net and nurture world-beating designers and scientists, in which group I'd gladly include Noma's Redzepi. **—Cenk Sumen**

Good story to read if you're on a diet.

—Ken Stailey

4

Q+A: Peter Thiel

Peter Thiel thinks incrementalism can't lead to anything revolutionary. But different people doing incremental things may very well be what is needed. The Apollo program would not have been possible without incremental developments that happened decades earlier. The same is true of the Manhattan Project and his other examples. **—acowan**

Tech feeds the lowest common denominator because that's where the money is. "Get in, make $10 million, get out again." Isn't that the dream of every Silicon Valley twenty-something? **—anonymole**

5

Confessional in the Palm of Your Hand

Being anonymous doesn't equal being honest. So besides the haters, trolls, and scammers, you're reading the online equivalent of the *National Enquirer*. **—rykk.dekk**

Ten years ago, we were afraid of losing our online privacy when our real names became attached to our comments on Facebook. Now we're seeing companies created to bring that anonymity back, and with that comes freedom of expression, creativity, and honesty. That's why I'm all for companies like Whisper and Secret.

—lamoore

What Does Technology Have to Do with Inequality?

In "Technology and Inequality" (November/December), David Rotman invokes what economists call "skill-biased technological change" as the answer to why wealth chasms have grown so deep in recent years. This leads him to the most commonly cited remedy: more education.

There's of course a lot to be said for this solution: the returns to education are historically high, and many less advantaged households face growing barriers to higher education. The trouble is that the data don't support nearly as large a role for technology as Rotman suggests. We've always had technological change in our economy, and there's no evidence it's more biased toward skill now than it was in the past. Even as recently as the late 1990s, a period of pervasive and diffuse computerization, middle- and low-wage workers benefited from a strongly growing economy and a uniquely tight labor market.

Rotman believes that there are two main ways in which technology is driving inequality. First, he says computerization has evolved in such a way as to raise both the cognitive demands that employers make of their workers and the paychecks of the workers who can meet those demands. Second, he subscribes to the "winner-take-all," or superstar, theory. The idea is that the Internet, in tandem with its low marginal costs of reproducing and delivering information, has vastly expanded markets for those with something people want, whether it's the next killer app or the next Taylor Swift song.

A real challenge for Rotman's argument is that all the new technology isn't showing up in productivity growth. If robotics and AI, for example, are as big an economic deal as his argument suggests, shouldn't they be boosting output with fewer inputs, the very definition of faster productivity growth? Yet productivity growth has slowed in recent years.

The late 1990s was the last time the U.S. job market was at full employment, and the tight labor market compelled employers to bid up wage offers to get and keep the workers they needed to meet the robust demand that we haven't seen since. So getting back to full employment, and restoring the bargaining clout that gives workers, must be at the top of any agenda designed to push back on inequality.

Rotman mentions globalization only in passing, but it's a much bigger deal than he lets on. We've run large trade deficits in this country for over three decades. In doing so, we've exported millions of good, middle-class jobs, largely in manufacturing. Our policy makers have done nothing in response.

It's not really the superstars—the Taylor Swifts of the world—who are driving up high-end inequality. It's CEOs and financial executives extracting "rents"—incomes well beyond their productive contributions—from a broken system of corporate governance.

Jared Bernstein is a senior fellow at the Center on Budget and Policy Priorities and a former economic advisor to Vice President Joe Biden.

Reply from the editor: *The feature, in fact, begins with the premise, described by the economist Thomas Piketty, that much of the wealth inequality is due to the unjustifiably high earnings of corporate executives. But there are likely many factors in today's inequality. I'm not sure why Mr. Bernstein mentions Taylor Swift, but it's hard to be in Silicon Valley these days without noticing the tech "superstars" and their wealth. The "winner-take-all" effect surely has something to do with it: can anyone name the No. 2 version of Twitter?*

CORRECTION:

"Microsoft's Quantum Mechanics" in the November/December issue erroneously referred to a likeness of Thomas Edison in the foyer of Bell Labs. The bust is of Alexander Graham Bell.

Views

Daphne Koller

John Elder Robison

Gabriella Coleman

COMPUTING

What MOOCs Teach Us

Online education offers one effective way to close the skills gap.

THREE YEARS AGO, SEVERAL OF US AT STANford launched the first massive open online courses, or MOOCs. We wanted to make the teaching of the world's great universities accessible to anyone with an Internet connection. The company we founded, Coursera, recently passed a milestone: 10 million enrolled learners. That makes it a good time to reflect on what we've learned.

One early prediction about MOOCs was that they would undermine or even replace the traditional college education—an idea we at Coursera never endorsed (see "What Are MOOCs Good For?" page 68).

And it hasn't happened—only 15 percent of our current learners are college age. The other 85 percent fall largely into two categories. The first are adults looking to expand their horizons. The second—nearly half of our learners—are working adults looking to build critical job skills for a better career. This shouldn't surprise anyone. The world around us is changing rapidly, and many of the skills you need today—data science, mobile apps, digital marketing—didn't even exist a decade ago.

How do we create an educational experience suited to this very different population? First, we can share our knowledge about learner interests with our university partners, who can experiment with new courses, new subject areas, and hands-on projects that align with problem-solving in real-world settings.

We also need to find the right delivery method. Working adults have many demands on their time; they have to structure their learning around their lives, rather than the other way around. For this reason, we're making the transition to an on-demand model that lets people engage with the content at their own pace.

Finally, we need to educate people on the value of this new type of credential. To complete a MOOC is a measure not only of job-related skills but also of qualities like dedication and self-motivation. Fortunately, these criteria are gaining credence—in a joint study by Duke University and RTI International, 73 percent of employers said that they would look favorably on MOOC completion in the hiring process. Many who have completed MOOCs have told us that they've gained tangible benefits, including new jobs, new responsibilities, and promotions.

The growing demand for alternative learning resources is a by-product of the ever-shifting skills gap. It's also a signal that a four-year degree is no longer sufficient for a lifelong career. MOOCs won't be the only solution to these much greater issues, but they can be an important component in transforming learning to better suit the needs of the 21st century.

Daphne Koller is cofounder and president of Coursera.

BIOMEDICINE

Fixing Autism Research

We need to come to grips with what autism really is.

AUTISM RESEARCHERS HAVE PUBLISHED thousands of papers in recent years. With those numbers, you'd think we'd all be rejoicing over great progress. Yet many people—especially autistic adults—are frustrated by how little benefit has actually materialized. Why?

The simple answer is, we're studying the wrong things. We're sinking millions into the search for a "cure," even though

ANDY FRIEDMAN

we now know that autism is not a disease but rather a neurological difference, one that cripples some of us while bringing a few others extraordinary gifts. Most of us live with a mix of exceptionality and disability. I know I do.

Research into the genetic and biological foundations of autism is surely worthwhile, but it's a long-term game (see "Solving the Autism Puzzle," page 36). The time from discovery to deployment of an approved therapy is measured in decades, while the autism community needs help right away.

If we accept that autistic people are neurologically different rather than sick, the research goal changes from finding a cure to helping us achieve our best quality of life.

Here are some ways we can do that:

We can remediate the crippling conditions that accompany autism. Anxiety, depression, seizure disorders, sleep disorders, and intestinal distress are the big ones, but there are more.

We can help autistic people organize their lives, manage their schedules, and regulate themselves in the face of sensory overload. Many of the things we ask for—like quiet spaces or calm lighting—are comforting to most anyone. But for us they are critical.

We can offer engineering solutions to the things autistic people can't do naturally. Some formerly nonverbal autistics talk through handheld tablets, and make friends with computer assistants like Siri. We're now seeing machines that read expressions even when we can't. Computers can improve anyone's quality of life, but we stand to benefit more than most from applied technology.

We can make life better for the autistic people who have major cognitive and functional challenges that today's science can't fix. We have a duty to make their lives better through applied technology. We owe it to our most disabled brothers and sisters to do all we can to ensure their security, safety, and comfort.

So how might this change in research direction come about? For one thing, we can put autistic people in charge. The fact is, researchers have treated autism as a childhood disability, when in fact it's a lifelong difference. If childhood is a quarter of the life span, then three-quarters of the autistic population are adults. Doesn't it make sense that some of us would want to take a role in shaping the course of research that affects us?

If you're a researcher with an interest in autism—and you want to really make a difference—open a dialogue with autistic people. Ask what they want and need, and listen.

John Elder Robison is a professor at the College of William & Mary and the author of Look Me in the Eye.

WEB

The World Needs Anonymity

There's a noble imperative behind not revealing who you are.

ANONYMITY IS UNDER ATTACK. "IT'S TIME to end anonymous comments sections," implored a recent op-ed in the *Washington Post*. In the U.K., a parliamentary committee has argued for a "cultural shift" in favor of treating pseudonymous comments as untrustworthy. There's even a popular Swedish TV show devoted to tracking down and publicly shaming people who post nasty anonymous comments online (see "The Troll Hunters," page 50).

Anonymity's value seems to be at a new low, and it's happening against a backdrop of never-ending surveillance. If it's not CCTV cameras watching our every move, it's companies and governments harvesting our digital data.

Anonymous speech may seem like the spawn of recent technology, but in truth there's a long history of anonymity being used for a positive purpose. The Federalist Papers were originally published under a pseudonym. The Supreme Court has repeatedly granted First Amendment protection to anonymous speech.

Imagine if everyone were forced to disclose their real identities online. We'd be discouraging potential whistle-blowers. We'd be discouraging anyone who wanted to voice an unpopular belief. Yes, anonymity can engender antisocial behavior—but it can also provide a means of pushing back against increased surveillance.

As an anthropologist, I've spent half a dozen years studying Anonymous, the collective best known for its crusades against dictators and corporations. My studies of this ragtag band of hackers and rabble-rousers has revealed to me how important the prospect of anonymity remains.

The group's ethic is partly indebted to 4chan, a popular and subversive image board that enforced the name "Anonymous" for all users, thus hatching the idea's potential. One activist explained the crucial role of 4chan in cementing "the primary ideal of Anonymous": "The posts on 4chan have no names or any identifiable markers attached to them. The only thing you are able to judge a post by is its content and nothing else."

Why care about this, if you're not an activist? You should care because Anonymous functions as a social laboratory where participants experiment with the power, threat, and promise of anonymity itself. Anonymous political acts are often portrayed as cowardly, but we can just as easily observe a noble imperative—anonymity displaces attention from the messenger to the message.

Gabriella Coleman is the author of Hacker, Hoaxer, Whistleblower, Spy: The Many Faces of Anonymous.

Views

COLLABORATION

On Creativity

How do people get new ideas?

PRESUMABLY, THE PROCESS OF CREATIVITY, whatever it is, is essentially the same in all its branches and varieties, so that the evolution of a new art form, a new gadget, a new scientific principle, all involve common factors. We are most interested in the "creation" of a new scientific principle or a new application of an old one, but we can be general here.

One way of investigating the problem is to consider the great ideas of the past and see just how they were generated. Unfortunately, the method of generation is never clear even to the "generators" themselves.

But what if the same earth-shaking idea occurred to two men, simultaneously and independently? Perhaps, the common factors involved would be illuminating. Consider the theory of evolution by natural selection, independently created by Charles Darwin and Alfred Wallace.

There is a great deal in common there. Both traveled to far places, observing strange species of plants and animals and the manner in which they varied from place to place. Both were keenly interested in finding an explanation for this, and both failed until each happened to read Malthus's "Essay on Population."

Both then saw how the notion of overpopulation and weeding out (which Malthus had applied to human beings) would fit into the doctrine of evolution by natural selection (if applied to species generally).

Obviously, then, what is needed is not only people with a good background in a particular field, but also people capable of making a connection between item 1 and item 2 which might not ordinarily seem connected.

Undoubtedly in the first half of the 19th century, a great many naturalists had studied the manner in which species were differentiated among themselves. A great many people had read Malthus. Perhaps some both studied species and read Malthus. But what you needed was someone who studied species, read Malthus, and had the ability to make a cross-connection.

That is the crucial point that is the rare characteristic that must be found. Once the cross-connection is made, it becomes obvious. Thomas H. Huxley is supposed to have exclaimed after reading *On the Origin of Species*, "How stupid of me not to have thought of this."

But why didn't he think of it? The history of human thought would make it seem that there is difficulty in thinking of an idea even when all the facts are on the table. Making the cross-connection requires a certain daring. It must, for any cross-connection that does not require daring is performed at once by many and develops not as a "new idea," but as a mere "corollary of an old idea."

Isaac Asimov

ANDY FRIEDMAN

It is only afterward that a new idea seems reasonable. To begin with, it usually seems unreasonable. It seems the height of unreason to suppose the earth was round instead of flat, or that it moved instead of the sun, or that objects required a force to stop them when in motion instead of a force to keep them moving, and so on.

A person willing to fly in the face of reason, authority, and common sense must be a person of considerable self-assurance. Since he occurs only rarely, he must seem eccentric (in at least that respect) to the rest of us. A person eccentric in one respect is often eccentric in others.

Consequently, the person who is most likely to get new ideas is a person of good background in the field of interest and one who is unconventional in his habits. (To be a crackpot is not, however, enough in itself.)

Once you have the people you want, the next question is: Do you want to bring them together so that they may discuss the problem mutually, or should you inform each of the problem and allow them to work in isolation?

My feeling is that as far as creativity is concerned, isolation is required. The creative person is, in any case, continually working at it. His mind is shuffling his information at all times, even when he is not conscious of it. (The famous example of Kekule working out the structure of benzene in his sleep is well-known.)

The presence of others can only inhibit this process, since creation is embarrassing. For every new good idea you have, there are a hundred, ten thousand foolish ones, which you naturally do not care to display.

Nevertheless, a meeting of such people may be desirable for reasons other than the act of creation itself. No two people exactly duplicate each other's mental stores of items. One person may know A

and not B, another may know B and not A, and either knowing A and B, both may get the idea—though not necessarily at once or even soon.

Furthermore, the information may not only be of individual items A and B, but even of combinations such as A-B, which in themselves are not significant. However, if one person mentions the unusual combination of A-B and another the unusual combination A-C, it may well be that the combination A-B-C, which neither has thought of separately, may yield an answer.

It seems to me, then, that the purpose of cerebration sessions is not to think up new ideas but to educate the participants in facts and fact combinations, in theories and vagrant thoughts.

But how to persuade creative people to participate? First and foremost, there must be ease, relaxation, and a general sense of permissiveness. The world in general disapproves of creativity, and to be creative in public is particularly bad. Even to speculate in public is rather worrisome. The individuals must, therefore, have the feeling that the others won't object.

If a single individual present is unsympathetic to the foolishness that would be bound to go on at such a session, the others would freeze. The unsympathetic individual may be a gold mine of information, but the harm he does will more than compensate for that. It seems necessary to me, then, that all people at a session be willing to sound foolish and listen to others sound foolish.

If a single individual present has a much greater reputation than the others, or is more articulate, or has a distinctly more commanding personality, he may well take over the conference and reduce the rest to little more than passive obedience. The individual may himself be extremely useful, but he might as well be put to work solo, for he is neutralizing the rest.

The optimum number of the group would probably not be very high. I should guess that no more than five would be wanted. A larger group might have a larger total supply of information, but there would be the tension of waiting to speak, which can be very frustrating. It would probably be better to have a number of sessions at which the people attending would vary, rather than one session including them all. (This would involve a certain repetition, but even repetition is not in itself undesirable. It is not what people say at these conferences, but what they inspire in each other later on.)

For best purposes, there should be a feeling of informality. Joviality, the use of first names, joking, relaxed kidding are, I think, of the essence—not in themselves, but because they encourage a willingness to be involved in the folly of creativeness. For this purpose I think a meeting in someone's home or over a dinner table at some restaurant is perhaps more useful than one in a conference room.

It seems necessary to me that people be willing to sound foolish and listen to others sound foolish.

Probably more inhibiting than anything else is a feeling of responsibility. The great ideas of the ages have come from people who weren't paid to have great ideas, but were paid to be teachers or patent clerks or petty officials, or were not paid at all. The great ideas came as side issues.

To feel guilty because one has not earned one's salary because one has not had a great idea is the surest way, it seems to me, of making it certain that no great idea will come in the next time either.

Yet your company is conducting this cerebration program on government money. To think of congressmen or the general public hearing about scientists fooling around, boondoggling, telling dirty jokes, perhaps, at government expense, is to break into a cold sweat. In fact, the average scientist has enough public conscience not to want to feel he is doing this even if no one finds out.

I would suggest that members at a cerebration session be given sinecure tasks to do—short reports to write, or summaries of their conclusions, or brief answers to suggested problems—and be paid for that, the payment being the fee that would ordinarily be paid for the cerebration session. The cerebration session would then be officially unpaid-for, and that, too, would allow considerable relaxation.

I do not think that cerebration sessions can be left unguided. There must be someone in charge who plays a role equivalent to that of a psychoanalyst. A psychoanalyst, as I understand it, by asking the right questions (and except for that interfering as little as possible), gets the patient himself to discuss his past life in such a way as to elicit new understanding of it in his own eyes.

In the same way, a session arbiter will have to sit there, stirring up the animals, asking the shrewd question, making the necessary comment, bringing them gently back to the point. Since the arbiter will not know which question is shrewd, which comment necessary, and what the point is, his will not be an easy job.

As for "gadgets" designed to elicit creativity, I think these should arise out of the bull sessions themselves. If thoroughly relaxed, free of responsibility, discussing something of interest, and being by nature unconventional, the participants themselves will create devices to stimulate discussion.

This previously unpublished 1959 essay by Isaac Asimov (1920–1992) was recently discovered by a friend of the author. Asimov wrote it when he was briefly part of a government-funded project tasked with finding creative approaches for a missile defense system. It is published with the permission of Asimov Holdings.

MARCH 13–17, 2015

SXSW® INTERACTIVE

AUSTIN, TX

REGISTER TO ATTEND

Last Discount Deadline: February 13

Walk-up Rates apply after February 13, 2015

ANNOUNCEMENTS, UPDATES, AND MORE:

sxsw.com/interactive

EXPERIENCE MORE

Brought to you by:

Miller Lite · esurance · AT&T · IFC Always On Slightly Off · mazda · Monster Energy · The Austin Chronicle

Upfront

How a Wiki Is Keeping Direct-to-Consumer Genetics Alive

The FDA ordered 23andMe to stop selling its health tests. But for the intrepid, genome knowledge is still available.

By Antonio Regalado

SOPHIA FOSTER-DIMINO

Upfront

When Meg DeBoe decided to tap her Christmas fund to order a $99 consumer DNA test from 23andMe last year, she was disappointed: it arrived with no information on what her genes said about her chance of developing Alzheimer's and heart disease. The report only delved into her genetic genealogy, possible relatives, and ethnic roots.

That's because just a month earlier, in November 2013, the Food and Drug Administration had cracked down on 23andMe. The direct-to-consumer gene testing company's popular DNA health reports and slick TV ads were illegal, it said, since they'd never been cleared by the agency.

But DeBoe, a blogger and author of children's books, found a way to get the health information she wanted anyway. Using a Web service called Promethease, she paid $5 to upload her raw 23andMe data. Within a few minutes she was looking into a report with entries dividing her genes into "bad news" and "good news."

As tens of thousands of others seek similar information about their genetic disposition, they are loading their DNA data into several little-known websites like Promethease that have become, by default, the largest purveyors of consumer genetic health services in the United States—and the next possible targets for nervous regulators.

Promethease was created as a side project by Greg Lennon, a geneticist based in Maryland, and Mike Cariaso, a computer programmer. It works by comparing a person's DNA data with entries in SNPedia, a sprawling public wiki on human genetics that the two created eight years ago and run with the help of a few dozen volunteer editors.

Consumer DNA tests determine which common versions of the 23,000 human genes make up your individual genotype. As science links these variants to disease risk, the idea has been that genotypes could predict your chance of getting cancer or heart disease, or losing your eyesight. But predicting risk is tricky. Most genes don't say anything decisive about you. And if they do, you might well wish for a doctor at your side when you find out. "I don't believe that this kind of risk assessment is mature enough to be a consumer product yet," says David Mittelman, chief scientific officer of Gene by Gene, a genetic laboratory that performs tests.

In barring 23andMe's health reports, the FDA also cited the danger that erroneous interpretations of gene data could lead someone to seek out unnecessary surgery or take a drug overdose. Critics of the decision said it had more to do with questions about whether consumers should have the right to get genetic facts without going through a doctor. Now a question is whether Promethease and sites like it could, or should, be the next target of regulators.

To Barbara Evans, a professor at the University of Houston Law Center, the idea that people can gather DNA from one company and analyze it elsewhere is a significant legal development. Previously, the same lab that tested you would be the one to tell you what the results meant. But DNA information is essentially digital. "It's going to be quite difficult to regulate," Evans predicts. She believes services like Promethease could invoke free-speech arguments and other legal defenses if regulators ever approached them.

Since the FDA blocked 23andMe's reports, traffic to gene-interpretation sites has jumped.

MIT Technology Review tested several interpretation-only sites using DNA data of anonymous donors posted publicly by the Personal Genome Project, a data-sharing initiative started by Harvard Medical School. All the sites quickly reported gene variants contained in the files, although the number varied, from as few as 35 to as many as 17,667 for Promethease. Some of the reports were also more detailed than others.

TO MARKET

Maker Machine

HP Sprout

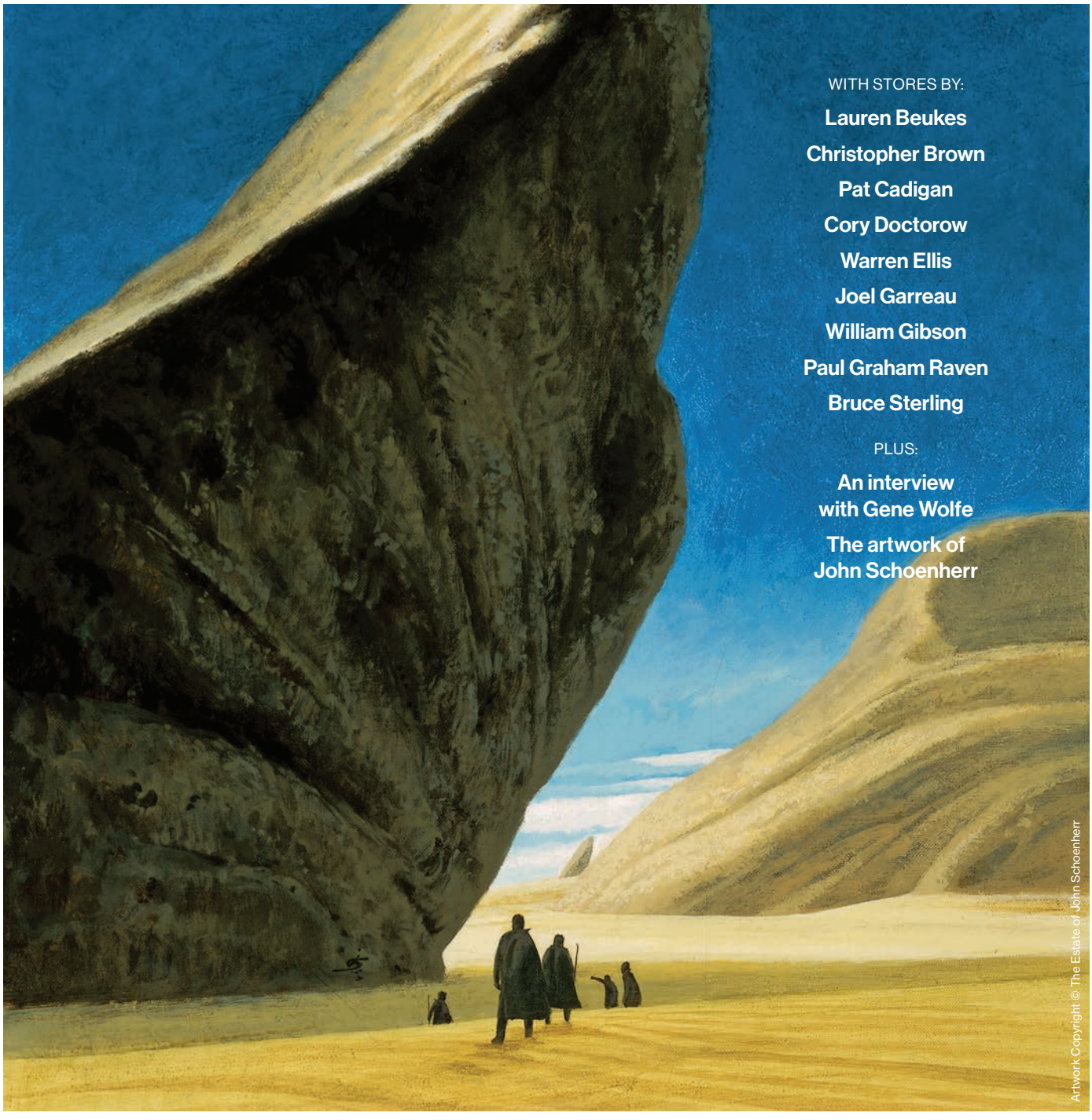
COMPANY:
Hewlett-Packard

PRICE:
$1,899

AVAILABILITY:
Now

COURTESY OF HEWLETT-PACKARD

HP has put together a Frankenstein's monster of a workstation by combining various computing, imaging, and interface technologies in one. HP's Sprout, as it's called, has a touch screen, a camera, infrared depth sensors, a projector, and a touch-sensitive whiteboard, as well as a conventional printer and scanner. It's also designed to hook up to a 3-D printer, to streamline the process of designing and prototyping objects. You might, for instance, use the device to scan a product in 3-D and then use a stylus to modify the digital scan once it is projected onto the workstation's touch-sensitive surface. After you've made your changes, you can print the new design on paper or as a 3-D model.



TWELVE TOMORROWS

The 2014 edition of MIT Technology Review's SF anthology

Visionary stories of the near future inspired by today's new technologies

Available for iPad, Kindle, and as a limited edition printed volume

Learn more:
www.technologyreview.com/twelvetomorrows

MIT Technology Review

Upfront

Two of the sites appeared designed to steer users toward alternative medicine. Genetic Genie, a free service that carries ads for vitamins, reported the fewest genes, in what it called a "detoxification profile." LiveWello charged $19.95 and included more genes, as well as links to scientific reports. That site, however, directed users to get an "explanation" of the results by contacting chiropractors, dieticians, and mind-body healers whose telephone numbers it provided.

The Promethease report was the most detailed, although its clunky, bare-bones design is not easy to use. The information is similar to that in 23andMe's banned "Personal Genome Service," but there are differences. Promethease makes little effort to combine the genetic risks for any disease into a single number. That makes the report more like a jumble of facts than a diagnosis. Lennon says this is intentional. He says 23andMe stepped on shaky scientific ground by trying to merge risks into one neat score.

"Everyone wants to sell a simple answer: 'Here is your risk.' But we don't know how these things interact," he says. At the same time, he believes the uncertain value of DNA information is not a reason to keep it away from laypeople.

For now, consumers have to fend for themselves in a thicket of scientific information—and make their own decisions about risks. To Lennon and Cariaso, the surge of interest in Promethease and SNPedia represents a triumph for a no-frills approach to genetics. In 2006, the same year 23andMe was founded, they launched SNPedia as a site that would let them—and anyone else—keep tabs on what science was learning about each gene variant. Lennon says the site was modeled on Wikipedia. "That was the promise of the genome, that it should be for everybody," he says. He didn't want investors involved. As a result, their work was overshadowed by 23andMe, which raised $126 million and hired more than a dozen PhD geneticists to curate its own gene lists. Its CEO, Anne Wojcicki, who is married to Google cofounder Sergey Brin, landed on magazine covers, and a board member predicted that her startup would "become the Google of personalized health care."

It didn't happen that way. And following the FDA's action to block 23andMe's reports, traffic to interpretation-only sites jumped. Interpretome, maintained by Konrad Karczewski, a postdoctoral researcher at Massachusetts General Hospital, now has 80 to 100 visitors per day, twice as many as last year. Even more are heading to Promethease. Lennon says the site averages between 50 and 500 reports per day, including a free version and a faster-running paid product. He won't get too specific about the numbers or say how much money Promethease is earning. "We are somewhat shy about saying how much business we are doing," he says.

That could be out of a desire not to rouse regulators. The FDA has wide discretion to act but often chooses to ignore small-time operators that bend the rules, especially if they avoid making overt health claims. But Cariaso and Lennon can't say they didn't anticipate trouble. After all, they named their software after Prometheus, the titan who defied the gods by stealing fire from Mount Olympus and giving it to mankind. (According to myth, he was later punished and chained to a rock for eternity.)

"Fire is knowledge of your own DNA," says Cariaso. "The gods are anyone who would try to prevent me from knowing about myself."

3 QUESTIONS

John Kelly

The head of IBM Research hopes to commercialize technologies related to its Watson computer.

When did you realize the importance of the technology behind Watson?

I'd always personally been fascinated with AI. But it was the learning machine aspect that was impressive. We would take new questions to ask the system, and it would answer, and I remember sometimes it was like, "Oh my god, how did it do that?" That's when I realized this is much bigger than a *Jeopardy!* game machine.

How is that changing IBM Research?

We're betting billions of dollars, and a third of this division now is working on [related technology]. As we developed and built Watson, we became convinced it was time for a huge leap forward. It became obvious that this wasn't just some step forward in AI, but that a whole new era was going to come about. That what we call "cognitive computing" is not only going to happen, it's going to completely transform industries.

What does that mean for other areas of IBM Research?

People who might've been working on old relational databases or something are now working on this. We're hiring every natural-language expert we can find, and we've already got some of the world's best. The underlying physics and materials, and the devices to power this next generation of systems, are of great interest to us. That is a grand challenge.

—Will Knight

PING ZHU; SOPHIA FOSTER-DIMINO

UNPLUGGED **PRODUCTIVITY**

NeatConnect®

CLOUD SCANNER + DIGITAL FILING SYSTEM

Do more in less time.

NeatConnect lets you send scanned items straight to your favorite cloud services and more. You can even send scans as emails – all without ever turning on a computer.

Work wherever you want.

Put NeatConnect where your paper is. Its integrated Wi-Fi and touchscreen interface let it do its job from virtually any room in the house, or any spot in the office.

Simplify your life.

Neat streamlines your day-to-day workflow and gives you more time to do what you want. Find any document fast, organize everything digitally, and stop wasting time with paper.

NEATCONNECT SCANS DIRECTLY TO:

NeatCloud® SkyDrive box EVERNOTE Dropbox Google Drive

neat®

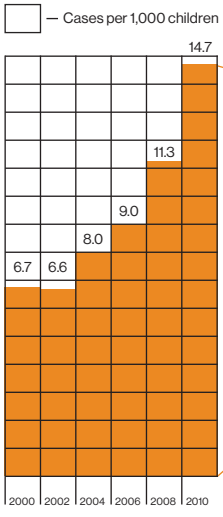
Order NeatConnect now & get **3 FREE MONTHS of NeatCloud**

▸ Call **866-395-4805** ▸ Visit **www.neat.com/review**

Upfront

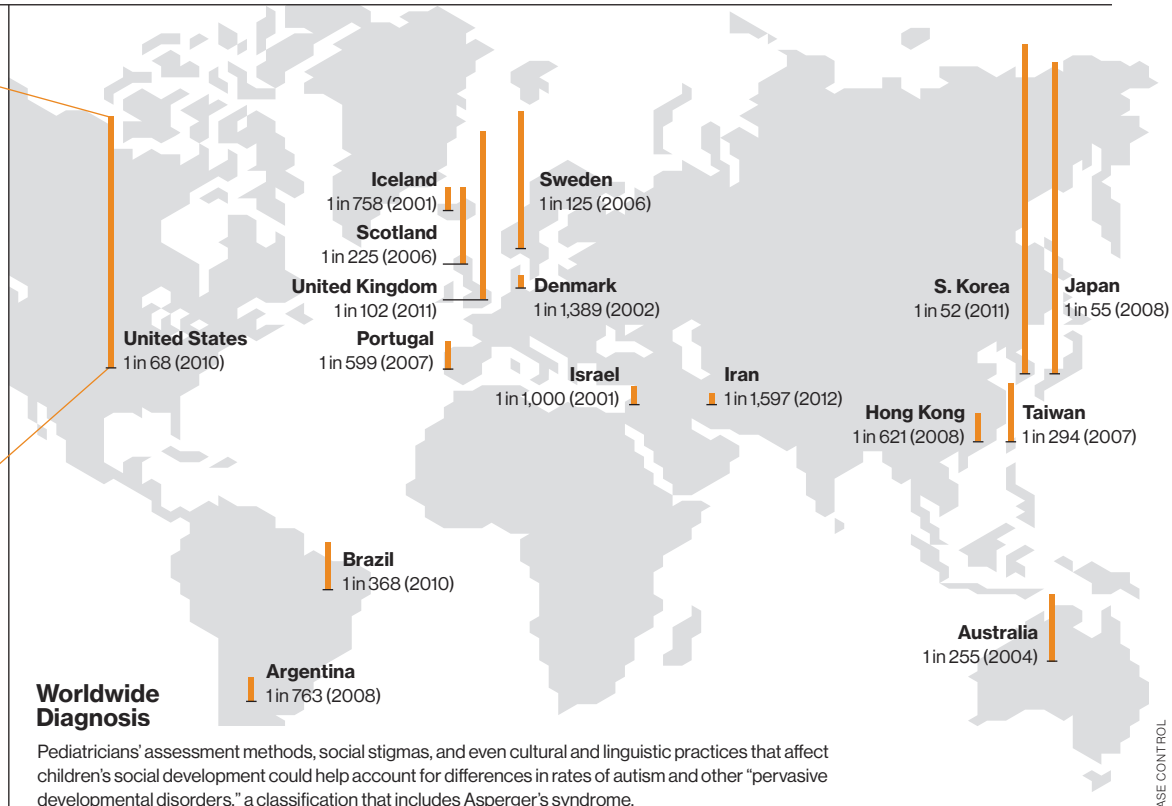
The Mystery of Autism

One of the things that make autism disorders so perplexing (see the story on page 36) is that there are no universal criteria for diagnosis. That's one reason the prevalence among children is all over the map.



Rising Rate of Autism

It's not clear why U.S. prevalence doubled in a decade. Much of the rise might have come from doctors seeing autism in children who previously would have gotten other diagnoses, such as mental retardation.



Worldwide Diagnosis

Pediatricians' assessment methods, social stigmas, and even cultural and linguistic practices that affect children's social development could help account for differences in rates of autism and other "pervasive developmental disorders," a classification that includes Asperger's syndrome.

Male-Female Ratio No one knows why there are disparities in autism rates even within countries, as seen in 11 states that the U.S. Centers for Disease Control and Prevention monitors for developmental disabilities. Even with the variation in overall cases, one pattern holds: autism affects around four times as many boys as girls.

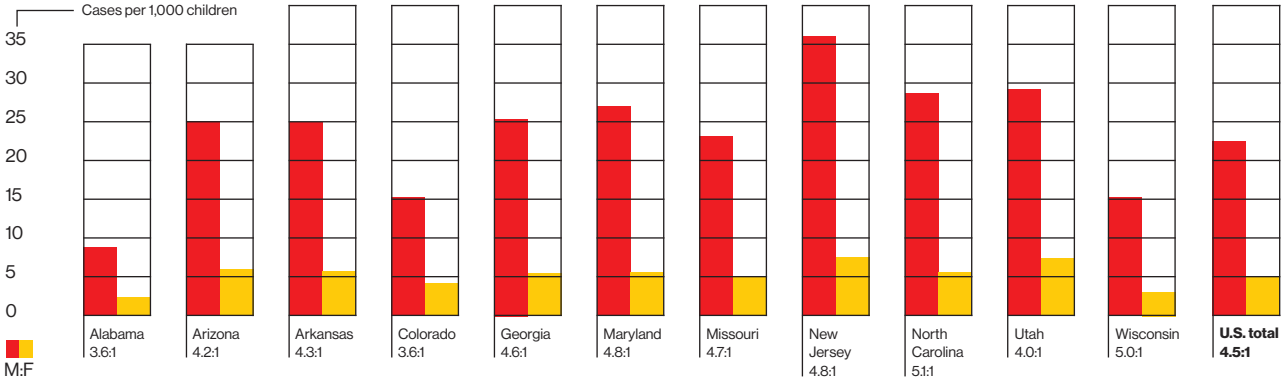


ILLUSTRATION BY LUKE SHUMAN; DATA ON PREVALENCE FROM CENTERS FOR DISEASE CONTROL AND PREVENTION AND EL-SABBAGH ET AL., *AUTISM RESEARCH*

141

The number of patents awarded to Steve Jobs since his death in October 2011.

JOHN MALTA

Voice Recognition for the Internet of Things

Wit.ai wants to give developers the tools they need to make smartphones, wearables, and appliances heed your call.

By Rachel Metz

It's not unusual to find yourself talking to an uncoöperative appliance or gadget. Soon, though, some devices might actually pay attention.

A startup called Wit.ai plans to make it easy for hardware makers and software developers to add custom voice controls to everything from Internet-connected thermostats to drones to smart watches. While big companies like Apple and Google have their own voice recognition technology, smaller companies and independent developers don't have the deep pockets required to create voice software that continuously learns from mountains of data.

Wit.ai, based in Palo Alto, California, is taking aim at the swiftly growing number of devices with small displays, or no screen at all, and at activities like driving and cooking, where you don't want to look at or touch a display.

The company is offering its product free to those who agree to share their user data with the Wit.ai community. Collecting this data should help improve the accuracy of the system over time. "Everyone will benefit from that," cofounder and CEO Alex Lebrun says.

With Wit.ai, developers type a few plain-English commands they want it to recognize, such as "Wake me up tomorrow at 6" or "Wake me up in 20 minutes," and note what they want to accomplish through each command—in this case, set the alarm on a hypothetical voice-controlled smart watch. Wit.ai uses what it knows about language to figure out the different ways a command might be expressed.

Then, when a user wants to set the alarm for a specific time, that person's utterances are sent to a Wit.ai server, which analyzes the audio and sends structured data back to the gadget—here, the instruction to set the alarm for the proper date and time.

Already, about 4,600 developers are using Wit.ai with things like mobile apps, robots, home automation, and wearable devices. Nick Mostowich, a student at the University of Waterloo in Ontario, is one of them. At a hackathon at his school, his team used Wit.ai to add voice control to a toaster and a microwave.

Mostowich says they quickly put together a set of commands and targets that could be mapped to a list of recipes on a remote server, so a user could say something like "Cook me some bacon" and the microwave would turn itself on, set to the right power level and time.

Voice-powered bacon-nuking aside, Wit.ai still has plenty of obstacles to overcome. Like many similar systems that rely on the cloud, it's not quick to respond, and it can't work if you don't have an Internet connection.

And while Wit.ai can be used with Spanish, French, German, Italian, and Swedish, it's still far better in English. However, Lebrun believes that as more data is added, non-English languages will improve. And he hopes to enable developers to use Wit.ai without needing an Internet connection. The system could just occasionally check in with Wit.ai's servers to update its learning.

Upfront

With $100 Million, Entrepreneur Hopes to Overturn the Business of Medical Imaging

The goal of ultrasound on a chip: for anyone to get a "window" into the body.

By Antonio Regalado

With a scanner the size of an iPhone, you could look inside a person's chest and see a vivid, moving, 3-D image of what's inside.

That's the goal of entrepreneur Jonathan Rothberg, who says he has raised $100 million to create an imaging device that's nearly "as cheap as a stethoscope" and will "make doctors 100 times as effective." According to patent documents, the technology relies on a new kind of ultrasound chip. It could eventually lead to new ways to destroy cancer cells with heat, or deliver information to brain cells.

Rothberg has a knack for matching semiconductor technology to problems in biology. He started and sold two DNA-sequencing companies, 454 Life Sciences and Ion Torrent Systems, for more than $500 million. The profits have allowed him to ply the ocean on a 130-foot yacht named *Gene Machine* and to indulge high-concept hobbies like sequencing the DNA of mathematical geniuses.

The imaging system is being developed by Butterfly Network, a three-year-old company that is the furthest advanced of several ventures Rothberg says will be coming out of 4Combinator, an incubator he has created to start and finance companies that combine medical sensors with a branch of artificial-intelligence science called deep learning.

Rothberg won't say exactly how Butterfly's device will work, or what it will look like. "The details will come out when we are on stage selling it. That's in the next 18 months," he says. But he guarantees it will be small, cost a few hundred dollars, connect to a phone, and be able to do things like detect breast cancer or visualize a fetus.

Butterfly's patent applications describe its aim as building compact, versatile new ultrasound scanners that can create 3-D images in real time. Hold the scanner up to a person's chest and you would look through "what appears to be a window" into the body, according to the documents.

Jonathan Rothberg

With the $100 million supplied by Rothberg and investors, which include Stanford University and Germany's Aeris Capital, Butterfly appears to be placing the largest bet yet by any company on an emerging technology in which ultrasound emitters are etched directly onto a semiconductor wafer, alongside circuits and processors. The devices are known as capacitive micromachined ultrasound transducers, or CMUTs.

Most ultrasound machines use small piezoelectric crystals or ceramics to generate and receive sound waves. But these have to be carefully wired together and then attached via cables to a separate box to process the signals. Anyone who can integrate ultrasound elements directly onto a computer chip could manufacture them cheaply in large batches and more easily create the type of arrays needed to produce 3-D images. Doctors use ultrasound more often than any other type of imaging test—for example, to view a baby during pregnancy, to find tumors in soft tissues like the liver, and, recently, to treat prostate cancer by heating up cells with sound waves.

The idea for micromachined ultrasound chips dates to 1994, when Butrus Khuri-Yakub, a Stanford professor who advises Rothberg's company, built the first one. But none has been a commercial success, despite a decade of interest by companies including General Electric and Philips. That is because the chips haven't functioned reliably and have proved difficult to manufacture.

"The vision for this product has been around for many years. It remains to be seen whether someone can make it into a market-validated reality," says Richard Przybyla, head of circuit design at Chirp Microsystems, a startup in Berkeley, California, that's developing ultrasound systems that let computers recognize human gestures. "Perhaps what was needed all along is a large investment and a dedicated team."

Rothberg says he got interested in ultrasound technology because his oldest daughter, now a college student, has tuberous sclerosis. Symptoms of the disease can include seizures and the develop-

A. RICHARD ALLEN

$127

The cost per megawatt-hour, in the European Union, of solar power according to a recent analysis, compared with $115 for nuclear, $102 for offshore wind, $50 for coal and natural gas, and $10 for hydropower.

ment of dangerous cysts in the kidneys. In 2011 he underwrote an effort in Cincinnati to test whether high-intensity ultrasound pulses could destroy the kidney tumors by heating them.

What Rothberg saw led him to conclude there was room for improvement. The setup—an MRI machine to see the tumors and an ultrasound probe to heat them—cost millions of dollars, but it wasn't particularly fast. It was more like a "laser printer that takes eight days to print and looks like my kids drew it in crayon," he says. "I set out to make a super-low-cost version of this $6 million machine, to make it 1,000 times cheaper, 1,000 times faster, and a hundred times more precise."

Rothberg claims Butterfly's technology has a "secret sauce" he won't reveal. But it may have as much to do with clever device

The vision for this product has been around for many years. It remains to be seen if someone can market it.

and circuit design as with overcoming the physical limits and manufacturing problems that CMUT technology has faced so far. One reason to think so is that the company's cofounder, Nevada Sánchez, previously helped cosmologists design a much cheaper radio telescope with a signal-processing trick called a butterfly network—the origin of the startup's name. Also working with the company is Greg Charvat, who previously worked at MIT's Lincoln Laboratory to develop radar that can see human bodies even through thick stone walls.

During a visit to 4Combinator's headquarters, inside a marina in Guilford, Connecticut, Charvat and Sánchez showed me a picture of a penny so detailed you could read the letters and numbers on it. They'd taken the image using a prototype chip. "The ultrasound [industry] is basically back in the 1970s. GE and Siemens are building on old concepts," says Charvat. With chip manufacturing and a few new ideas from radar, he says, "we can image faster, with a wider field of view, and go from millimeter to micrometer resolution."

Ultrasound works by shooting out sound and then capturing the echo. It can also create beams of focused energy—and chip-based devices could eventually lead to new systems for killing tumor cells. Small devices might also be used as a way to feed information to the brain (it was recently discovered that neurons can be activated with ultrasonic waves).

Rothberg says his first goal will be to market an imaging system cheap enough to be used even in the poorest corners of the world. He says the system will depend heavily on software, including techniques developed by artificial-intelligence researchers, to comb through banks of images and extract key features that will automate diagnoses.

"We want it to work like 'panorama' on an iPhone," he says, referring to a smartphone function that steers a picture taker to pan across a vista and automatically assembles a composite image. But in addition to recognizing objects—body parts, in the case of a fetal exam—and helping the user locate them, Rothberg says the system would reach preliminary diagnostic conclusions with the aid of pattern-finding software.

"When I have thousands of these images, I think it will become better than a human in saying 'Does this kid have Down syndrome, or a cleft lip?' And when people are pressed for time, it will be superhuman," says Rothberg. "I will make a technician able to do this work."

QUOTED

"The notion that—with hundreds of thousands of coders around the world—no one is going to give software consciousness is not credible."

— Martine Rothblatt, chief executive of United Therapeutics and author of *Virtually Human: The Promise—and the Peril—of Digital Immortality*

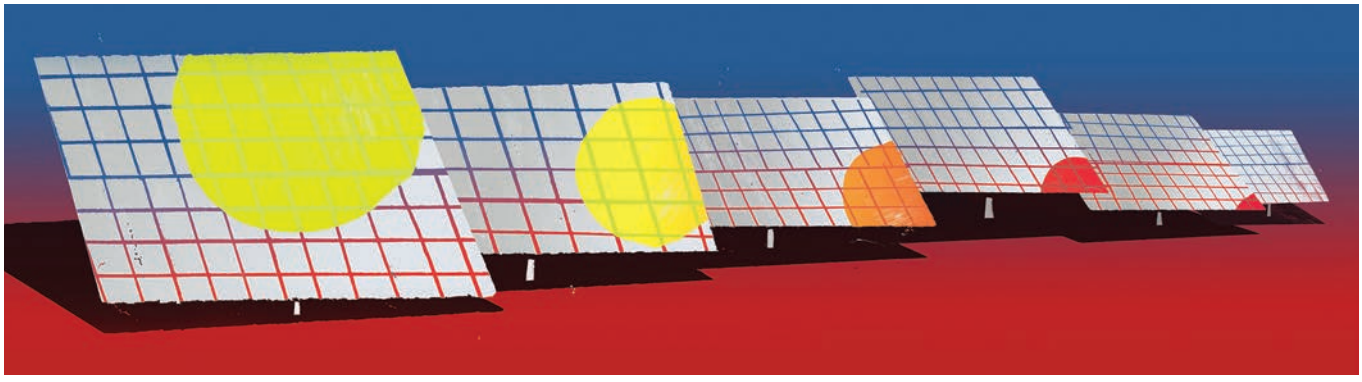
"It seems purely speculative, as if someone has drawn a cartoon and said they are going to fly to Mars with it."

— Ian Hutchinson, professor of nuclear science and engineering at MIT, on Lockheed Martin's claims that it has a promising way to reliably generate electricity from fusion

"For some people the effect is really profound. Within minutes, they're feeling significantly different, in a way that is as powerful as anything I could imagine short of a narcotic."

— Marom Bikson, a professor at City College of New York, who has tested a "mood-altering" brain stimulation device developed by a company called Thync

Upfront



Will a Breakthrough Solar Technology See the Light of Day?

A startup that might have a record-breaking solar cell is in danger of going out of business.

By Kevin Bullis

The power unit is a rectangular slab about the size of a movie screen. It's mounted on a thick steel post and equipped with a tracking mechanism that continuously points it at the sun. The slab is made of over 100,000 small lenses and an equal number of even smaller solar cells, each as big as the tip of a ballpoint pen. And it is part of one of the most efficient solar-power devices ever made.

Semprius, a startup based in Durham, North Carolina, claims that the next generation of this power unit will make solar power the cheapest option for utilities installing new power plants. With fields of over 1,000 of these devices, utilities would produce electricity at less than five cents per kilowatt-hour. That is even cheaper than the output of a new natural-gas plant.

The technology originated in the lab of John Rogers, a professor at the University of Illinois. Semprius has raised $45 million from investors including Siemens and has set records for solar-cell efficiency. This year it demonstrated that it could use a version of its technology to make a novel kind of solar cell that, some believe, could convert half the energy in sunlight into electricity—an efficiency about three times better than conventional solar cells offer.

Yet for all the promise of the technology, Semprius is in a tough spot. For its technology to be cost-effective, it must scale up the production of its solar cells significantly. Right now it can make enough solar units to produce six megawatts of power per year, but it needs to get to at least 200 megawatts. The company is raising $40 million in hopes of doing this. Its current investors say they'll contribute, and for now they're lending the company money to keep it in business, but they won't do so forever. Semprius needs a new investor soon. Otherwise, it could go under.

TO MARKET

Gene Reader

Mini-ION

COMPANY:
Oxford Nanopore

PRICE:
$1,000

AVAILABILITY:
Now

A new kind of gene sequencing instrument has been reaching scientific labs over the past few months. Whereas other commercial sequencing machines cost millions, are the size of refrigerators, and require jugs of pricey chemicals, it is four inches long and gets its power from a USB port on a computer. The device measures DNA directly as the molecule is drawn through a tiny pore in a membrane. Changes in electrical current are used to read off the chain of genetic letters: A, G, C, and T. Today's fastest sequencers decode DNA after it's been shredded into tiny bits, just 150 letters at a time. Mini-ION should make it easier for researchers to reassemble a genome.

DANIEL ZENDER, COURTESY OF OXFORD NANOPORE TECHNOLOGIES

This predicament has become a familiar one for solar startups. Founded in 2005, Semprius took part in a wave of venture capital investments a couple of years later that funded hundreds of new solar companies. It's one of only a few of those companies still standing. Many of the others failed or were acquired for pennies on the dollar. Investors lost more than $1 billion. The resulting backlash has made it difficult for any solar company, regardless of its merits, to get the investment it needs to prove its technology.

"In 2007, venture capitalists were throwing money at solar companies," says Scott Burroughs, Semprius's chief technology officer. "All you'd have to have is 'solar' in your name—or at least start with the letter S. Now it's the exact opposite. Instead of throwing money at companies, they're not even considering one if it's associated with solar."

That raises a disturbing possibility—might a breakthrough technology that could make solar power truly competitive never see the light of day?

Unlike many earlier solar startups that gambled on developing entirely new manufacturing equipment, Semprius mostly uses inexpensive, off-the-shelf equipment, some of it from the LED industry. At its pilot factory in Henderson, North Carolina, the company's key technology can be found inside two glass-enclosed devices, each not much bigger than an office copier. At the end of a robot arm is a rubber stamp embossed with a pattern that makes Semprius's high-efficiency, low-cost solar power possible.

The stamp, developed in Rogers's lab, allows Semprius to improve upon a type of solar power called concentrated photovoltaics, which has been around for decades. The idea is that you can increase the amount of energy a solar cell gathers by putting lenses over the cell to focus light into it. Semprius's stamp makes it possible to make arrays of solar cells that are far smaller and thinner than the ones that had been used in concentrated photovoltaics. For the concentrating technology to work, the solar cells need to be picked up and arranged in an array so they can be paired with an array of lenses—and that's where the rubber stamp comes in. It can pick up and transfer thousands of the tiny solar cells at once without breaking them, changing the economics.

Semprius's predicament has become a familiar one for solar startups that need money to scale up.

Small cells require only small amounts of material, so they can be made of expensive types of semiconductors that are far more efficient than silicon. They also dissipate heat well and can operate under very concentrated sunlight.

These advantages, and some clever lens designs, allowed Semprius to break a solar-power efficiency record in 2012. More recently, it demonstrated that the rubber stamps could quickly and accurately stack cells made of different semiconductors on top of each other. Researchers have wanted to do this for some time, since it would allow them to match semiconductor materials to various parts of the solar spectrum. Some wavelengths of light would be absorbed by one material, the rest would pass to the semiconductors below, and so on.

Siemens acquired its stake in Semprius in 2011. After a detailed examination of its technology, says Thomas Mart, the global head of solar activities at Siemens, "what we saw is a way to get to very low costs of electricity." But 15 months after Siemens invested, things fell apart. Huge investments in conventional silicon solar power, especially in China, had lowered costs of production—and flooded the market with cheap solar panels. Dozens of promising solar startups failed and the projected market for concentrated photovoltaics shrank, convincing Siemens to get out of the business.

Making matters worse for Semprius, conventional silicon solar panels still have room to become significantly cheaper and more efficient. New ways of manufacturing silicon wafers, the most expensive part of a solar cell, could cut wafer costs in half or better. And new designs are edging up the efficiencies of solar cells.

But silicon-based solar power is not yet there, and that's the opportunity for Semprius. The U.S. Energy Information Administration estimates that new solar power plants will produce power at just under 15 cents per kilowatt-hour—far higher than the 6.5 cents per kilowatt-hour for natural-gas power. If Semprius is right that it will soon have technology to make solar panels capable of producing electricity at around five cents per kilowatt-hour, its technology could be attractive to those planning new power plants. "No invention is required—just good, solid engineering," Burroughs says.

So Semprius continues its search for a new investor to scale up its technology, pursuing leads in China and Mexico, says Burroughs. Meanwhile, the existing investors are keeping the company going, but "not because we're into giving charitable gifts," says Clinton Bybee, a venture capitalist at Arch Venture Partners. "We believe this could be very big."

DANIEL ZENDER

Q+A

Shanley Kane

Shanley Kane heads one of the most interesting new publications that cover technology: *Model View Culture*, a quarterly journal and website that offers a remorseless feminist critique of Silicon Valley. The derisive point of view taken by the publication was honestly won: Kane worked for five years in operations, technical marketing, and developer relations at several infrastructure companies. Frustrated by the unexamined assumptions of her industry and irritated by the incompetence of her managers, she began blogging about technology culture and management dysfunction, which led her to found *Model View Culture*. She spoke to *MIT Technology Review*'s editor in chief, Jason Pontin.

Silicon Valley imagines itself open to anyone with talent, but its companies are often more homogeneous in composition than other corporations. Why is that?
The Valley has bought into the idea of itself as a meritocracy: a world of self-starting, bootstrapping geniuses so much better and smarter than anyone else in the world that they deserve wildly disproportionate opportunities for wealth and power. The problem is that this is the exact opposite of what Silicon Valley *actually* is: a sexist and racist wealth distribution mechanism that relies on cronyism, corruption, and exclusion to function.

You think technology companies take a kind of perverse pride in being unprofessionally managed.
The technology industry sees itself as in rebellion against corporate America: not corrupt, not buttoned-up, not empty. In fact, a tech company can be as corrupt, soulless, and empty as any corporation, but being unprofessional helps us maintain the belief that we are somehow different from Wall Street.

Technologists love to celebrate the hacker and the programmer. What roles are undervalued by the industry?
Obviously, programmers are important, but a very common dysfunction, particularly at technology startups, is privileging programmers. When you don't value other skills, your engineering team becomes very entitled and even abusive of other parts of the company. Really important functions, like marketing, sales, business development, finance, and legal, become underfunded and underresourced. We often end up with companies with great technology that are nonetheless dying because they could not execute from a nontechnical standpoint.

Why are there relatively few women in the tech industry? Is it a so-called pipeline problem, in that not enough women train as programmers and engineers? Or is it because women leave the industry?
Obviously the pipeline is a huge issue. But too often, our industry focuses on early stages of the pipeline that they have no control over. You see venture capitalists talk about the need to get more 10-year-old girls into programming, and that's so far removed from their direct sphere of influence. Meanwhile, there is attrition in every stage of the career path of women once they get into the industry. Over 50 percent of women will leave by the halfway point in their careers. We are not getting hired, and we are not getting promoted, and we are being systematically driven out of the industry.

How often are women not given the credit that they deserve for the creation of a company?
When they are hired into early roles at the company, people from marginalized groups—including women—don't get the same amount of stock, and they are not given the titles. And many times they're not brought into the company until later stages of a company's development, so they miss out on the opportunity to be part of the founding team. We particularly see underrepresentation of black founders. And in general, we give too much credit to individual white male founders when companies are comprised of many people who have [devoted] their lives to [making] their organizations work.

Have you seen signs of improvement at all in some of these issues that you write about?
I'm not one to be optimistic about these things, but if pressed I can come up with a few examples. We are getting codes of conduct at events, and while that seems like a superficial thing, it does reflect awareness that our events are places where people are having bad experiences, where there is inequality and sometimes very serious abuse. Another thing I have seen over the past two years is that there is a lot more social-media organization and activism, which is helping to change the way people view tech and its problems. The final thing that's good is that this year the Rainbow PUSH Coalition did a ton of work to get technology companies to share all their diversity data, which is forcing a lot of these issues into the open. There's not any excuse for pretending that we don't know.

Describe Silicon Valley in one word.
Maybe I'll go with "corrupt."

OPEN INNOVATIONS
Forum and Exhibition

Open Innovations Forum 2014

3,968 Forum participants, including:

2,921 participants from **64** regions of the Russian Federation and **1,047** participants from **71** foreign countries

738 representatives of startup teams

40 embassies

Over **100** Russian and foreign universities and research institutes

9 universities from the top of the Times Higher Education World University Rankings 2014-2015

476 experts in innovation from **29** countries

30 investment funds

22 companies listed in Fortune Global 500

35 companies listed in Forbes' Global 2000 Leading Companies 2014

223 events of the business program of the Forum and Expo

497 one-on-one meetings on the venue of the Forum

Open Innovations Expo 2014

13000 м^2 exhibition area

16 770 visitors

490 companies from **17** countries

18 collective expositions of Russian regions

240 м^2 collective exposition of the People's Republic of China (partner country of the Forum and Expo)

More than **3000** students of Moscow colleges and universities

Over **2000** students from 85 schools of Moscow and Moscow region

13 collective expositions of Russian institutes for development and professional associations

88 events of the Exhibition's business program

Messages from Forum Keynote Speakers

Arkady Dvorkovich, Deputy Prime Minister of the Russian Federation:

«Countries can only ensure their competitiveness through brisk technological advancement. «Open Innovations» not only has shown what had Russia achieved in the sphere of innovations recently, but has also become a unique platform for face-to-face communication between experts, entrepreneurs and representatives of development institutes from different states».

Zhores Alferov, RAS Academician, Nobel laureate in physics 2000:

«Growth of civilization is defined by science. Scientific research lays foundation for new technology. New technological boom should be primarily expected at the confluence of biology, physics and chemistry».

Joe Liu, Vice President, Research & Development International & Asia Pacific, 3M:

«If we do not move forward, we move backward. If we do not implement innovations, if the process of creative disruption and constant reshaping does not happen inside the company, if the company does not create anything inside itself – then we begin to fall behind».

Wan Gang, Minister of Science and Technology of the People's Republic of China:

«Cooperation between Russia and China have expanded and improved by many different forms. This enables us to make even bigger contribution to the scientific-technological development of our countries and creates even more favorable environment for their innovative development».

Bertrand Piccard
Chairman and Pilot of Solar Impulse:

«I don't think that electric bulb was invented by chandlers. Narrow specialization often hinders creation. Innovations should be born outside systems. Working at the confluence of different technologies inspires creativity and refusal to old approaches and convictions. Building horizontal communications is needed in order to achieve the result».

We will be glad to see you in Moscow in October 2015!
Follow updates on the website www.forinnovations.org

The way the Land of the Rising Sun built and lost its dominance in photovoltaics shows just how vulnerable renewables remain to changing politics and national policies.

By Peter Fairley

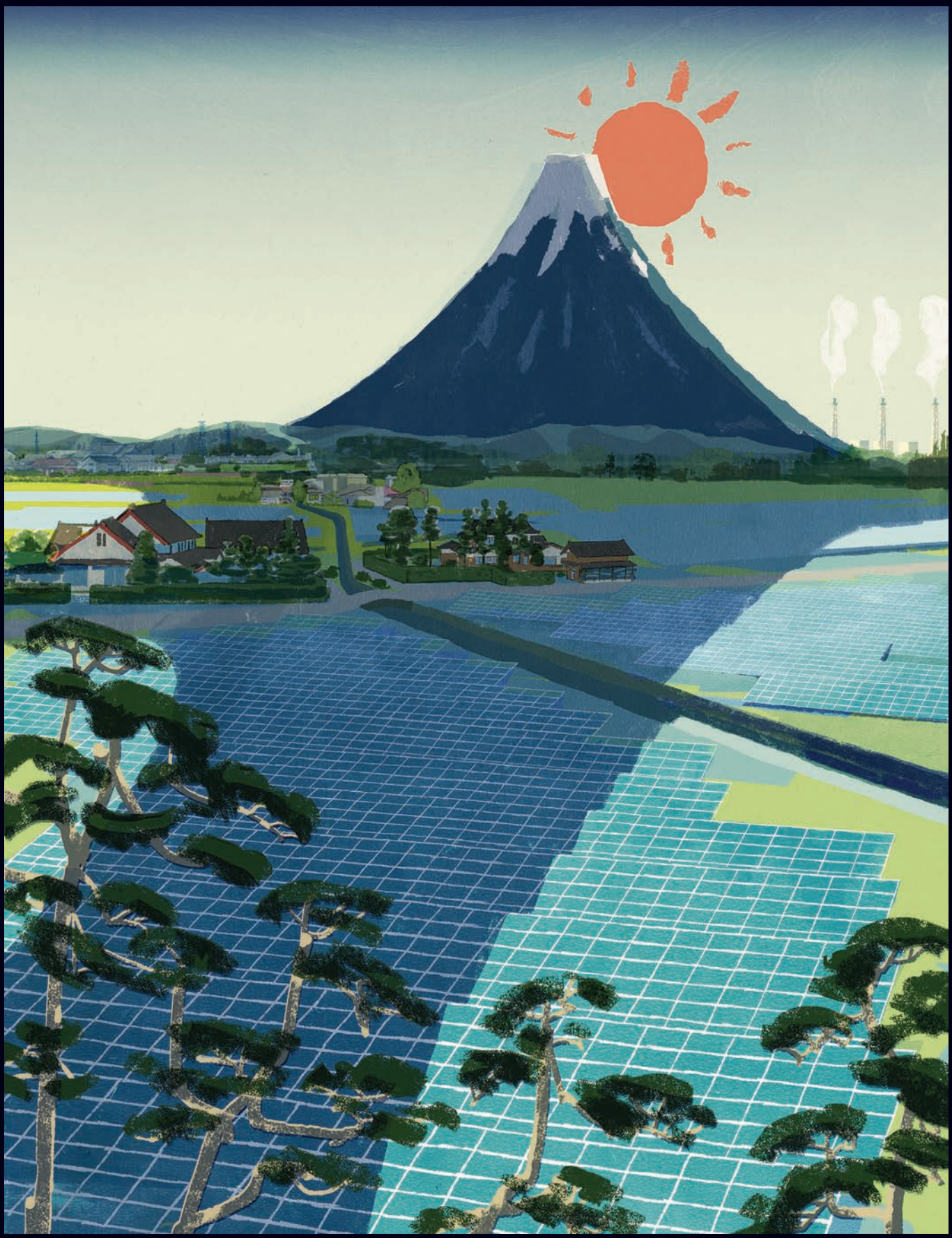
Can Japan Recapture Its Solar Power?

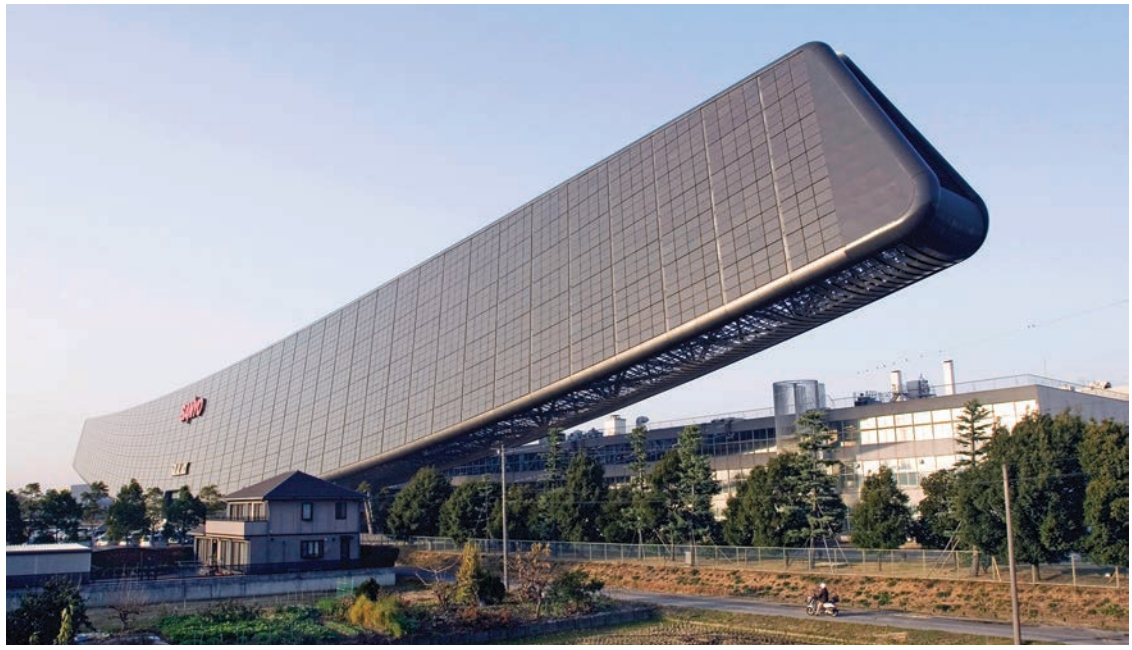
It's 38 °C on the Atsumi Peninsula southwest of Tokyo: a deadly heat wave has been gripping much of Japan late this summer. Inside the offices of a newly built power plant operated by the plastics company Mitsui Chemicals, the AC is blasting. Outside, 215,000 solar panels are converting the blistering sunlight into 50 megawatts of electricity for the local grid. Three 118-meter-high wind turbines erected at the site add six megawatts of generation capacity to back up the solar panels during the winter.

Mitsui's plant is just one of thousands of renewable-power installations under way as Japan confronts its third summer in a row without use of the nuclear reactors that had delivered almost 30 percent of its electricity. In Japan people refer to the earthquake and nuclear disaster at Tokyo Electric Power Company's Fukushima Daiichi nuclear power plant on March 11, 2011, as "Three-Eleven." Radioactive contamination forced more than 100,000 people to evacuate and terrified millions more. It also sent a shock wave through Japan's already fragile manufacturing sector, which is the country's second-largest employer and accounts for 18 percent of its economy.

Eleven of Japan's 54 nuclear reactors shut down on the day of the earthquake. One year later every reactor in Japan was out of service; each had to be upgraded to meet heightened safety standards and then get in a queue for inspections. During my visit this summer, Japan was still without nuclear power, and only aggressive energy conservation kept the lights

TATSURO KIUCHI





Sanyo Electric's so-called Solar Ark, built in 2001 during the heyday of the country's initial solar boom, was designed to generate 630 kilowatts of power, making it one of the world's largest solar facilities. It boasts 5,046 solar panels.

on. Meanwhile, the country was using so much more imported fossil fuel that electricity prices were up by about 20 percent for homes and 30 percent for businesses, according to Japan's Ministry of Economy, Trade, and Industry (METI).

The post-Fukushima energy crisis, however, has fueled hopes for the country's renewable-power industry, particularly its solar businesses. As one of his last moves before leaving office in the summer of 2011, Prime Minister Naoto Kan established potentially lucrative feed-in tariffs to stimulate the installation of solar, wind, and other forms of renewable energy. Feed-in tariffs set a premium rate at which utilities must purchase power generated from such sources.

The government incentive is what motivated Mitsui to finally make use of land originally purchased for an automotive plastics factory that was never built because carmakers moved manufacturing operations overseas. The site had sat idle for 21 years before Mitsui assembled a consortium to help finance a $180 million investment in solar panels and wind turbines. By moving fast, Mitsui and its six partners qualified for 2012 feed-in tariffs that promised industrial-scale solar facilities 40 yen (35 cents) per kilowatt-hour generated for 20 years. At that price, says Shin Fukuda, the former nuclear engineer who runs Mitsui's energy and environment business, the consortium should earn back its investment in 10 years and collect substantial profits from the renewable facility for at least another decade.

Overnight, Japan has become the world's hottest solar market: in less than two years after Fukushima melted down, the country more than doubled its solar generating capacity. According to METI, developers installed nearly 10 gigawatts of renewable generating capacity through the end of April 2014, including 9.6 gigawatts of photovoltaics. (The nuclear reactors at Fukushima Daiichi had 4.7 gigawatts of capacity; overall, the country has around 290 gigawatts of installed electricity-generating capacity.) Three-quarters of the new solar capacity was in large-scale installations such as Mitsui's.

POLARIS

An image from Japanese television captures smoke rising after a hydrogen explosion at Fukushima Daiichi's unit 3 on March 14, 2011, days after the initial earthquake. Following the Fukushima disaster, all the country's nuclear reactors were shut down.

AP IMAGES

Yet this explosion of solar capacity marks a bittersweet triumph for Japan's solar-panel manufacturers, which had led the design of photovoltaics in the 1980s and launched the global solar industry in the 1990s. Bitter because most of the millions of panels being installed are imports made outside the country. Even some Japanese manufacturers, including early market leader Sharp, have taken to buying panels produced abroad and selling them in Japan.

How Japan—once the world's most advanced semiconductor producer and a pioneer in using that technology to manufacture photovoltaic cells—gave away its solar industry is a story of national insecurity, monopoly power, and money-driven politics. It is also a tale with important lessons for those who believe that the strength of renewable technologies will provide sufficient incentives for countries to transform their energy habits.

In Japan, for most of the 2000s, impressive advances in photovoltaics were ignored because the country's powerful utilities exerted their political muscle to favor nuclear power. And despite resurging consumer demand for solar power and strong public disdain for nuclear, the same thing could happen again. Will a country with few fossil-fuel resources and bleak memories of the Fukushima disaster take advantage of its technical expertise to recapture its position as a leading producer of photovoltaics, or will it turn away from renewable energy once more?

Riches

Longer than three football fields and over 37 meters tall, the Solar Ark is clearly visible from the Tokkaido Shinkansen as the bullet train crosses central Japan. The structure, covered with photovoltaic panels, looks like a temple of energy from another era—a time when Japan owned the solar-power industry. Sanyo erected the Ark in 2001, arraying on it 5,046 solar panels capable of generating 630 kilowatts of pollution-free electricity.

The era that gave rise to this feat began with the energy crises of the 1970s, when spiking global petroleum prices pummeled Japan's export-driven manufacturing economy. The country harnessed its dominance in the production of electronic semiconductor chips to pursue alternatives for cleaner, safer power in photovoltaics. And unlike other countries, such as the United States, it stuck with the resulting solar development programs even when oil prices dropped in the 1980s. Between 1985 and 2007, Japanese researchers filed for more than twice as many patents in solar technologies as rival U.S. and European inventors combined. Companies like Sharp, Sanyo Electric, Panasonic, and Kyocera became the clear leaders in solar technology. Japanese producers began ramping up sales and solar installations in the 1990s. By 2001 total solar-power output in Japan was 500 times higher than it had been a decade earlier—a decade in which U.S. solar generation edged up by a meager 15 percent.

Then it all came crashing to a halt a decade ago as the country staked its future on nuclear power.

The government's nuclear plans were ambitious: by the time Fukushima Daiichi melted down, they would call for 14 additional reactors by 2030, which would have nearly doubled nuclear generation to account for 50 percent of Japan's power supply. Meanwhile, photovoltaic sales in Japan declined during the mid-2000s, and by 2007 Japanese producers had ceded global market leadership to U.S., Chinese, and European manufacturers. In just a few years, the country had gone from industry leader to has-been.

What turned Japan away from the sun was a pernicious blend of perception, culture, and politics. Nuclear power had an aura of strength, while energy based on intermittent renewable power sources looked weak and unreliable—an impression encouraged by the country's politically powerful utilities. Though Japan has numerous locations that are ideal for wind and solar power, power companies convinced the public that energy choices were limited. "We are really severely of the mind-set that we lack resources and that Japan has to depend on imported fuel," says Mika Ohbayashi, director of the Tokyo-based Japan Renewable Energy Foundation.

The utilities' view was colored by self-interest. Japan's 10 utilities were (and remain) vertical monopolies. Each controls power generation, transmission, and distribution in its respective region, and its grids are designed to deliver electricity from centralized power plants—including large nuclear reactors. They lack, by design, the interconnections that facilitate the safe use of variable power generation. In most industrialized countries, governments have broken up the monopolies in power markets, freeing operators of transmission grids to

A Parallel History

SOLAR

1961: Sharp makes a prototype transistor radio that uses solar cells.

1963: Japan installs a 242-watt solar array, the world's largest, on a lighthouse.

1976: Sharp sells the first calculators with solar cells.

1980: Sanyo produces the first solar cells from thin films of amorphous silicon.

1991: Kyocera installs Japan's first grid-connected solar plant.

1992: Sharp reports record efficiency of 22 percent for solar cells suitable for mass production.

1994: Japanese producers commercialize residential solar modules.

1998: Kyocera becomes the world's largest producer of solar cells.

2001: Sanyo builds a 630-kilowatt "solar ark."

2004: Government ends rebate for residential rooftop solar panels.

2012: Feed-in tariff provides incentives for renewable power.

2013: Kyocera starts up a 70-megawatt solar plant, the largest in Japan.

2014: Panasonic reports a silicon solar cell with record-breaking efficiency.

NUCLEAR

1966: Japan's first commercial nuclear power reactor, a 160-megawatt unit, begins operating.

1971: TEPCO's first nuclear reactor, a 460-megawatt light-water reactor, begins operations in Fukushima.

1995: TEPCO's nuclear power reaches one billion megawatt-hours.

1997: TEPCO completes the Kashiwazaki-Kariwa plant, with a capacity of 8.2 gigawatts.

2002: The government's 10-year plan calls for the addition of nine to 12 new reactors by 2011.

2011: Nuclear power, generated at over 50 reactors, accounts for 30 percent of the country's electricity.

2011: In the aftermath of the Fukushima accident, many of the country's reactors are shut down.

2012: The last operating reactor, the Tomari plant in Hokkaido, is shut down. Reactors at the Oi plant restart two months later.

2013: Oi plant shuts down for maintenance, leaving Japan without nuclear power.

2014: Officials approve restart of the Sendai nuclear power plant, the first since more stringent post-Fukushima safety regulations.

build those interconnections, but Japan's utilities have bucked the deregulation trend. The interconnection problem is further compounded by an artifact: two AC frequencies that split the country's electrical system in half. Eastern Japan operates at 50 hertz, while western Japan uses 60-hertz power—a barrier that proved crippling in 2011, in the immediate aftermath of the Fukushima disaster, when a suddenly underpowered Tokyo could access little of Osaka's surplus power.

What turned Japan away from the sun was a pernicious blend of perception, culture, and politics.

Asked why Japan chose not to push solar power aggressively when it dominated the global industry, former prime minister Kan told me he puts the blame squarely on the country's utilities: "The reason is very clear. The electric power companies, the people who wanted to promote nuclear power, were opposed."

Revival

In a subdivision spreading over reclaimed land in the bay in Ashiya, a city between Osaka and Kobe, a 400-unit residential development called Smart City Shio-Ashiya ("Salty-Ashiya") is taking shape, the brainchild of the Panasonic subsidiary PanaHome. On a Sunday in July, solar panels atop each of the 50 houses built to date are pumping surplus power into the local grid, and PanaHome salespeople are selling a couple with toddlers on the homes' energy benefits and earthquake resistance.

Shio-Ashiya's two-story homes include geothermal heating and cooling and other green design features to minimize power consumption, while the high-efficiency rooftop solar panels maximize power generation. The surplus power should, according to PanaHome saleswoman Saho Watanabe, earn residents roughly 100,000 yen ($825) each year. Watanabe touts another feature, which should be invaluable when the grid goes down—say, in an earthquake or typhoon. She opens a cupboard in the dining room of a model home to reveal a lithium battery that, working with an energy management system near the kitchen, can run the family's AC/heat pumps, first-floor lighting, and refrigerator for about two days.

Panasonic's solar hopes rest on a technology invented by researchers at Sanyo in the 1990s and acquired by Panasonic four years ago when the corporations merged. The solar cells combine conventional crystalline-silicon and thin-film amorphous-silicon technologies to achieve relatively high efficiency in converting sunlight to electricity. Called HIT, for heterojunction with intrinsic thin layer, the hybrid technology has become a mainstay of the company's solar strategy.

Shingo Okamoto, a materials scientist who spent his career at Sanyo Electric before becoming director of solar R&D for Panasonic's EcoSolutions business group, says the panels are earning premium pricing in domestic sales because they produce far more electricity from a given rooftop than the cheaper polycrystalline panels that dominate the market. Assuming that each household consumes electricity at the Japanese average of 1,400 kilowatt-hours per year during daylight hours, he says, a household with the Panasonic system will have 52 percent more surplus power to return to the grid than a home with an ordinary solar system.

Residential power in Japan is pricey—at 24.33 yen (20 cents) per kilowatt-hour in 2013, it was nearly double the U.S. average. And given that electricity prices are "sure to keep going up," says Okamoto, the most efficient rooftop photovoltaic systems will have a strong advantage. When we met in July at Panasonic's Shiga plant, east of Kyoto, the plant had just started shipping its newest and most powerful panel design. The advances behind the panel, which uses cells with an efficiency of 22.5 percent, include a light-scattering film on the backside to enhance light absorption. Assembly lines were running 24 hours a day to keep up with domestic demand.

Further advances are in the pipeline. In April, Okamoto's group produced a silicon solar cell that reached 25.6 percent efficiency, breaking a 15-year-old world record of 25.0 percent. Though the record was set in the lab using a prototype device, Okamoto predicts that the group will ultimately be able to produce commercial cells whose efficiency is within a few percentage points of crystalline silicon's theoretical limit, 29 percent.

Repowering

Across the coastal mountains from the smashed reactors at Fukushima Daiichi and the contaminated landscape they created, one of the world's most advanced facilities dedicated to renewable-energy R&D is gearing up. The $100 million complex opened in April in Koriyama, Fukushima Prefecture's commercial center, and pulls together previously disparate research by Japan's science and technology agencies. The insti-

tute is not here by accident. It's an explicit commitment to the emotionally and economically devastated region.

The verdant prefecture north of Tokyo remains depopulated after the earthquake, tsunami, and meltdowns of March 2011. Many of the more than 100,000 residents rendered homeless by the disasters will never return. Replacing lost residents and businesses in an area known for radioactive contamination is not easy. Solar-powered radioactivity monitors in Koriyama show that the air is safe, but 100 kilometers to the east, Tokyo Electric Power Company (TEPCO) still struggles to keep contamination from polluting both groundwater and the sea.

The Koriyama R&D facility boasts state-of-the-art labs for crystallizing, slicing, and patterning silicon wafers, and its production line can churn out up to 360 wafers an hour. Outside, a variety of photovoltaics are being tested, along with a modest-sized wind turbine and a large grid-connected battery. Its most ambitious program is directed by Makoto Konagai, one of Japan's most celebrated solar scientists, who has moved to Koriyama from the Tokyo Institute of Technology. His goal is to smash through the theoretical efficiency limit of silicon cells, demonstrating rates of 30 percent by 2016 and up to 40 percent by 2021. It is an ambitious plan, but three large manufacturers, including Panasonic, have signed on.

While some other researchers seek more efficient alternatives to silicon, which accounts for 90 percent of current solar production, Konagai seeks to redesign the silicon cell from top to bottom. One of his teams, for example, is developing a casting method to produce higher-quality silicon ingots. Another team is rethinking the way semiconductor structures are patterned to turn silicon wafers into cells: Konagai's plan is to etch or build vertical structures just a few nanometers across, almost 100,000 times narrower than the silicon wafer itself. If his simulations are good, the resulting nanowires or nanowalls will alter the electrical behavior of the silicon within, boosting its potential to absorb light and gather electrical charge.

In June 2011, Fukushima's previously pro-nuclear governor, Yuhei Sato, declared that Fukushima should pin its future on renewable energy. Community activists initiated dozens of projects across the prefecture, and in 2012 it set a goal of increasing renewable energy from 22 percent to 100 percent of its power supply by 2040.

The cold reality of Japan's energy predicament, however, is that such bold ambitions are likely to fall short. The type of solar expansion that can be expected from feed-in tariffs alone isn't likely to meet the prefecture's goals—or even to replace the power that Japan's nuclear fleet once delivered. And political and economic forces don't seem to favor policies that would expand renewables more dramatically.

Projections by the Japan Photovoltaic Energy Association, a Tokyo-based trade group, suggest that annual solar installations will peak this year just shy of seven gigawatts. The group predicts that total installed solar capacity in Japan will reach 102 gigawatts by 2030, which would be enough to meet only a small fraction of the country's electricity needs. Moderate deployment of wind power would provide some additional electricity. But Japan needs far more. While Japanese consumers and industry have cut power demand since 2011, utilities covered most of the nuclear shortfall by ramping up combustion of imported natural gas, petroleum, and coal. Fossil fuels accounted for some 89 percent of Japan's electricity generation in 2012. As a result, its total greenhouse-gas emissions were 7 percent higher that year than in 2010.

The prospects for renewable power could get worse. To hedge against the possibility that they may be unable to restart nuclear reactors, utilities are building a new generation of coal-fired power stations. By Ohbayashi's count, some 13 gigawatts of new coal-fired power generation are now in development.

Meanwhile, the relatively high cost of Japan's solar power threatens to incite a backlash against renewable energy, encouraged by the pro-nuclear utilities. "There is no doubt that with the current photovoltaics, power generation is expensive," says Okamoto, expressing his personal viewpoint rather than Panasonic's. He fears negative reactions from ratepayers, whose rising power bills pay the tariffs that fund photovoltaic systems on rooftops and at power plants like Mitsui Chemicals': "If we continue to expand our business with the current level of costs, we may have objections."

What's more, the old politics that favor nuclear power seem to be returning. Though opinion polls consistently show that a majority of Japanese oppose restarting the utilities' idled reactors, Prime Minister Shinzo Abe vows to restart those deemed safe by Japan's Nuclear Regulation Authority. In July the agency issued the first such certification, to a pair of reactors on the southern island of Kyushu—even though offsite emergency control centers mandated after Fukushima have yet to be completed and the reactors are dangerously close to an active volcano. Iodine pills were quickly distributed to the reactors' neighbors, and the precedent-setting restart is expected soon, after getting the green light from the local governor and the plant's host city, Satsumasendai, whose economy is crippled without the jobs, tax dollars, and business that the plant provides.

At the same time, utilities are delaying grid connections to renewable developments or imposing grid-upgrade fees that render renewable projects infeasible. The pushback is hitting

Workers watched in October as a crane lifted a section of a radiation shroud that had been placed over a reactor at Fukushima after the earthquake. Lifting the cover exposed the debris inside the destroyed building for the first time since 2011.

THE ASAHI SHIMBUN; GETTY IMAGES

wind power hardest. Japan's meager market for wind turbines has actually *slowed* since Fukushima.

This summer METI launched a committee to manage the implementation of new energy policies. One topic: recent efforts by utilities and the government to restrain further solar installations. Ohbayashi says METI is backpedaling because it misjudged the commercial potential of renewables and their potential impact on the utilities. Says Ohbayashi, "They didn't foresee the explosive growth of photovoltaics."

The Japanese government has plans to radically overhaul the country's balkanized wholesale market and power grid, preparing for a future in which producers compete for the right to deliver power. In that scenario, renewable energy could thrive.

The most critical step, however, is still years away: forcing the vertically integrated utilities to "unbundle" their power generation and transmission businesses. Unbundling is essential to create a level playing field for producers and a system optimized to deliver the cheapest and cleanest power available in real time.

Reëngineering the grid to accommodate massive flows of renewables such as wind and solar is a potentially expensive route for Japan. However, it's not necessarily more costly than the path back to nuclear that the current government and the utilities are charting. Factoring in the cost of insurance against accidents and upgrades to prevent them could double the cost of nuclear energy.

As former prime minister Naoto Kan told me, the disaster at Fukushima Daiichi has forever altered the economics of nuclear power. "In the past, nuclear power was said to be able to supply power at a very cheap cost, but we know now that is not correct," he said. "That calculation assumed that no accidents could occur. Now we know they can."

Peter Fairley is a contributing editor for MIT Technology Review.

For years scientists have struggled to find the causes of autism by looking for genes shared by families prone to the disorder. Now researchers taking a new approach have begun to unlock its secrets.

Solving the Autism Puzzle

By Stephen S. Hall

His name was David. He was 10 years old and, to put it bluntly, compellingly weird—especially in the buttoned-down, groomed normality of suburban Long Island in the early 1960s. At the time, Michael Wigler was a ninth-grade student in Garden City, and he liked to hang out at the home of his girlfriend. That's where he encountered David, her younger brother. Half a century later, he still can't get the boy out of his mind.

"He was just like from another planet—it was like meeting an alien," says Wigler, who ended up a little further east on Long Island as a geneticist at Cold Spring Harbor Laboratory. "He was so different from anybody I had ever met before. First of all, he threw his arms about a lot. And then he moved his head around a lot and would never look at you when he talked to you. And he had an uncanny knowledge of baseball statistics. And I just thought, you know, 'Boy, this guy is *really* different. I mean, he's not just a little different. He's very different.'"

In the 1950s and 1960s, children like David were pretty much anomalies without a name. Long after becoming a prominent cancer researcher, Wigler would mention him to colleagues, students, postdocs, writers, almost anyone. As one of those postdocs later recalled, "At the time, autism existed; they just didn't call it autism, so Mike didn't know this kid had that particular disorder." Nonetheless, Wigler had become fascinated by the biological mystery that might explain such aberrant behavior. "I think it's probably what got me interested in genetics," he says.

Wigler, now 67, indeed devoted his career to genetics, establishing a reputation as one of the most original and productive thinkers in cancer research. So it was a bit of a surprise when, about 10 years ago, he jumped into autism research. Even more surprising has been what he and a few other maverick geneticists began to find.

One of the things Wigler had seen in cancer is that the disease usually arises because of spontaneous mutations. Rather

Noah Erenberg, Little Boy, *2008*

Top: Nicole Appel, Vintage Tools*, 2013; bottom: David Barth,* Vogels (Birds)*, 2008*

than lurking in the population for generations and passing from ancestors to descendants, as in classic Mendelian illnesses like Huntington's disease, these noninherited mutations popped up in one generation. They were fresh new changes in the DNA—de novo mutations, in the jargon of geneticists. As a cancer researcher, Wigler developed new techniques for identifying them, and that led to another surprise. Some of these new mutations were often stunningly complex—not just little typos in the DNA, but enormous chunks of duplicated or missing text, which often created unstable, mistake-prone regions in chromosomes.

All that—the memory of David, his successes in understanding cancer genetics, and the resulting realization that a focus on inheritance might miss some of the most significant disease-causing genes—served as background when, in the spring of 2003, Wigler received a phone call from James Simons, a wealthy hedge fund manager and cofounder (with his wife) of the Simons Foundation, whose daughter had been diagnosed with an autism spectrum disorder. The foundation had received a grant proposal for a research project, and Simons asked Wigler if he would be willing to evaluate it.

The researchers had proposed hunting for autism genes using conventional methods to look for inherited mutations passed down through families. Wigler didn't mince his words. "I thought they were looking the wrong way," he says now. "And I didn't want to see all this wasted effort."

Wigler, still fascinated by the boy he'd met some 40 years earlier, threw his own hat in the ring. "Autism?" he recalls telling Simons. "Autism? *I* want to work on autism."

Beginning with a paper in *Science* in 2007 and culminating with a report published in *Nature* last October, Wigler's group and its collaborators have written a dramatically different story about the genetic origins of autism spectrum disorders—a story so unexpected and "out of left field," as Wigler puts it, that many other genetic researchers refused to believe it at first. Wigler and his colleagues have shown that many cases of autism seem to arise from rare de novo mutations—new wrinkles in the fabric of DNA that are not inherited in the traditional way but arise as last-minute glitches during the process in which a parent's sperm or egg cells form.

Importantly, these rare mutations exert big effects on neurological development and function. Wigler's methods have allowed researchers to zero in on numerous genes that are damaged in people with autism and begin to classify subtypes according to the genes involved. And they have begun to take the next step: using the specific genes as clues, they are working to identify critical pathways that may shed light on how the disorder works and suggest possible therapies.

Publishing Errors

It shouldn't be surprising that the genetics of autism make for an extremely difficult puzzle. After all, autism disorders cover a spectrum characterized by everything from atypical yet highly functional behavior to severe intellectual disability—a jumble of excitation and withdrawal, stunning intellectual capacity and severe mental disability, kinetic explosions of movement and repetitive actions, and other symptoms seen to varying degrees in different people. And yet much current research is predicated on the belief that the tiniest aberration at the level of genes, in the wrong place at the wrong time in development, can produce the kinds of aberrant behavior that are the hallmark of autism: social awkwardness and repetitive thinking and actions.

Earlier efforts to find autism's genetic causes were a total failure.

Since the disorder was first described in 1943, by Leo Kanner of Johns Hopkins, people have been vexed by its complex and paradoxical nature. Researchers have put forward a series of hypotheses that have not survived scientific scrutiny, attributing it to everything from emotionally remote mothers to ingredients in childhood vaccines. Genetics had always been an obvious route to explore, because it was known that autism often runs in families. So researchers have spent years gathering data on affected families and looking for suspicious mutations passed down from parent to child.

Geneticists pored over genomes in search of small shared errors in the DNA that were seen frequently enough to explain the disorder. But overall, these attempts were consistently uninformative; to use Wigler's characterization, they were "worthless." Though the search turned up a few common genetic variants found in people with autism, each of these variants has only an insignificant effect. The effort to find the genetic causes of autism by this strategy was "a total failure," says Gerald Fischbach, scientific director of the Simons Foundation.

That was precisely the point that Wigler made to James Simons when the foundation sought his advice. Wigler wanted to take the opposite approach: look for new mutations that were not shared by parents and children. Although extremely

ERENBERG COURTESY OF THE GOOD LUCK GALLERY; APPEL COURTESY OF PURE VISION ARTS

rare, these mutations were often very disruptive, creating devastating effects in a single generation; identifying them would be a much more effective way to discern which genes are especially important in autism. So Wigler urged the Simons Foundation to find families in which only one child had autism, while the parents and siblings did not. Thanks to their cancer research, he and his colleagues had already developed the technology to spot newly arising mutations, and it looked like a more powerful way to identify key autism-related genes, too.

Wigler's move into autism came at an important juncture in the biology of development disorders. It was one thing to implicate new mutations in cancer, a disease that often results from genetic insults to a person's DNA over a lifetime. It was quite another to suggest that de novo mutations played a major role in diseases that develop early in life. But scientists led by Wigler and a few others, including Evan Eichler at the University of Washington, had begun to find that the genome itself was not what previous researchers had envisioned.

While the Human Genome Project had presented genomic DNA as a single thread of letters (the "sequence"), and researchers had then catalogued variations consisting primarily of thousands of small differences of a letter or two, "new school" geneticists were finding oddities: huge duplications, gaping holes, and vast tracts of repetitive segments, known collectively as copy number variants. "Let's suppose you buy a book," Wigler says. "We're used to getting books where the cover's on right, the pages are in order, and they tell a continuous story. But imagine a publisher that duplicated his pages, dropped some pages, changed the order of the pages. That's what happens in the human genome. That's copy number variation."

This form of mutation turns out to appear with surprising frequency in the human genetic text. Wigler's group first glimpsed the phenomenon in cancer cells, but his hunch was that similar "publishing" errors might also play a role in diseases like autism. Sure enough, when the researchers examined the genomes of people with autism, they often found weird, large-scale duplications or deletions of DNA—mutations not present in the mother or father. The fact that they were not inherited strongly suggested that they were recent corruptions of the genetic text, almost certainly arising in the sperm or egg cells of the parents.

As more families participated in the research, and as technologies for identifying mutations improved, this body of work painted a new picture of the genetics of autism (indeed, the genetics of neurocognitive disorders more generally), confirming that de novo mutations and copy number variations account for many cases of the disorder. And these mutations seem to be especially prevalent in genes that affect neurological development and cognition.

In October, Wigler's group—with collaborators including Eichler at the University of Washington and Matthew State at the University of California, San Francisco—identified up to 300 genes potentially related to autism. Twenty-seven of them confer a significantly heightened risk when disrupted by these rare new mutations. Each specific de novo mutation is rare enough to be found in less than 1 percent of the autism population, but collectively they may account for 50 percent of all cases of autism, says the Simons Foundation's Fischbach.

Different Perspectives

Some individuals with autism and other developmental disorders are accomplished artists, creating work that illuminates their way of seeing the world. In this feature, we showcase five.

Noah Erenberg has been exhibiting his work for over 20 years. On the site promoting his art, he says, "I paint and draw because it makes me feel wonderful. I like to work outside and look around my neighborhood at the trees, the ocean and the surfers." He is represented by Good Luck Gallery in Los Angeles.

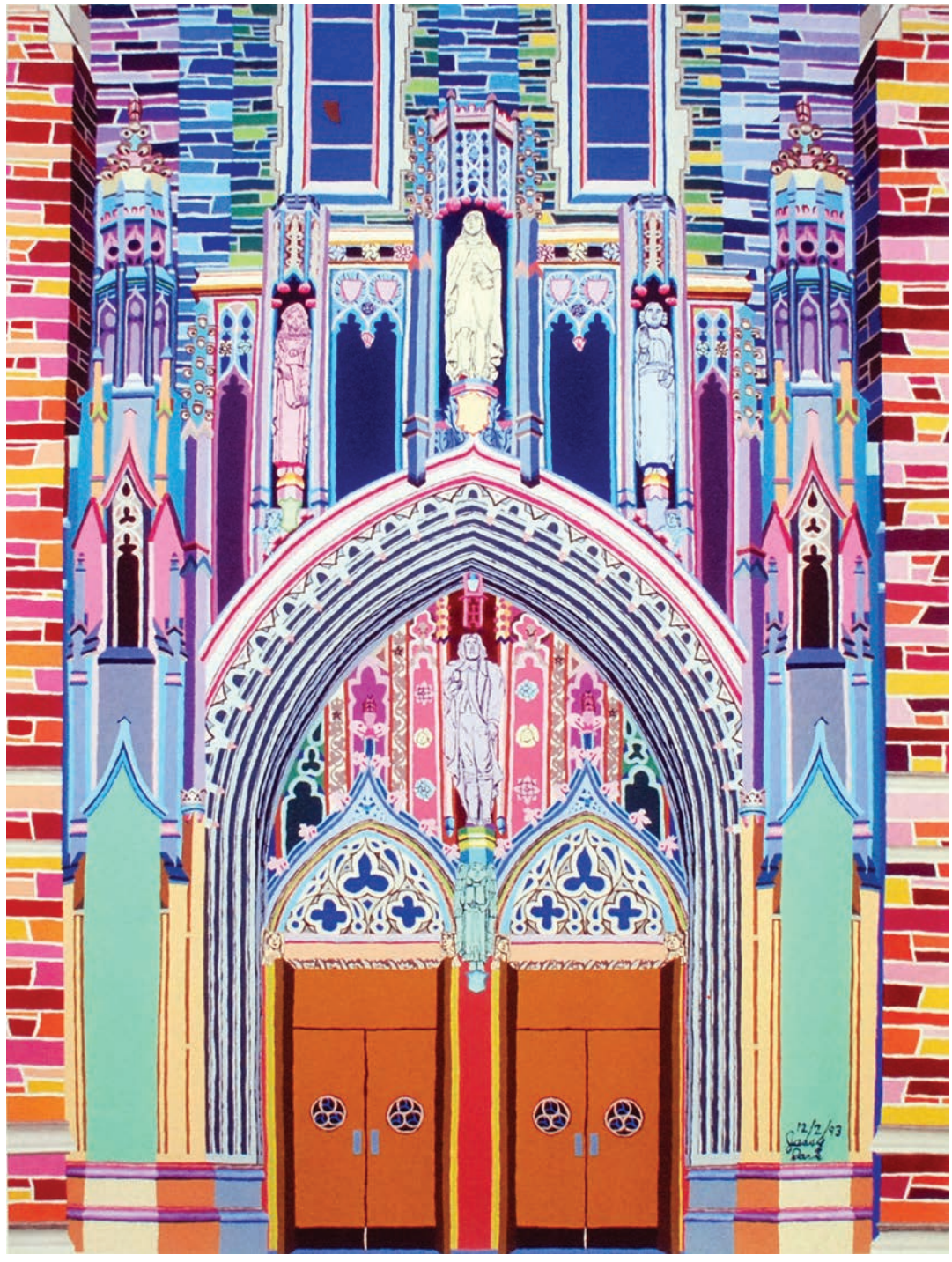
Nicole Appel is an artist in Queens, New York. On the site of Pure Vision Arts, a gallery that supports artists with autism and other disabilities, is a selection of her detailed pieces that often feature cultural icons and expressive images of people and animals.

David Barth's Tumblr.com site says that Asperger's syndrome "causes him to conceive the world in his own unique way." Barth, who was born in Rotterdam, Netherlands, in 1998, has won prizes for his drawings and has had several exhibitions of his work.

Jessica Park is a painter in Williamstown, Massachusetts. A 2008 book called *Exploring Nirvana: The Art of Jessica Park* documents her life and art.

Jeroen Pomp, who uses colored pencil on paper, has had several exhibitions at the Galerie Atelier Herenplaats in Rotterdam.

COURTESY OF PURE VISION ARTS



Jessica Park, The Duke University Chapel*, 1993*

Jeroen Pomp, Dieren en Planten (Animals and Plants)*, 2010*

Some of these genes are active in the earliest weeks of prenatal brain development; others kick into gear after birth. Some affect the function of synapses, the junctions between nerve cells; others affect the way DNA is packaged (and activated) within cells. One gene, *CHD8*, previously linked by Eichler's group to children with a severe form of autism, has also been linked to schizophrenia and intellectual disability. Subtypes of autism seem to be associated with mutations in certain genes, which may begin to explain such long-standing mysteries as why some cases of autism produce severe symptoms while others cause more modest behavioral tics.

The findings also provide insight into just why autism is so common. "Let me highlight a critical point, and one of the biggest insights to come from the genetics of autism," says Jonathan Sebat, a professor at the University of California, San Diego, who previously worked in Wigler's lab and helped to reveal this new genetic landscape. "We did not fully appreciate how plastic the genome is, in the sense of how much new mutation there is. The genome is mutating, evolving constantly, and there's a steady influx of new mutations in the population. Every child born has roughly 60 new changes in their DNA sequence, and [one in] every 50 children born have at least one large rearrangement. This is a really significant contributor to developmental disorders."

Another surprising discovery is that certain regions of the human genome seem especially prone to disruption. Not only do some of these genetic "hot spots" seem to be linked to many forms of autism, but some of them have a deep and significant evolutionary history. If you trace them back in time, as Evan Eichler's laboratory has begun to do, you can begin to glimpse the emergence of precisely the traits that distinguish humans from all other animals. "It's kind of a crazy idea," Eichler says, "but it's like autism is the price we pay for having an evolved human species."

Copy number variations in one specific hot spot on the short arm of chromosome 16, for example, have been associated with autism. By comparing the DNA of chimpanzees, orangutans, a Neanderthal, and a Denisovan (another archaic human) with the genomes of more than 2,500 contemporary humans, including many with autism, Xander Nuttle, a member of Eichler's group, has been able to watch this area on the chromosome undergo dramatic changes through evolutionary history.

At a meeting of the American Society of Human Genetics last fall, Nuttle reported that this mutation-prone region, which contains more than two dozen genes related to neurocognitive function, lies adjacent to an intriguing gene known as *BOLA2* that seems to promote instability. Nonhuman primates have at most two copies of the gene; Neanderthals have two; contemporary humans have anywhere from three to 14, and the multiple copies of the gene appear in virtually every sample the researchers have looked at. This suggests that the extra copies of the *BOLA2* gene, which predispose people to neurodevelopmental disorders like autism, must also confer some genetic benefit to the human species. Otherwise, evolutionary pressure would have scrubbed the duplications out of the genome. In other words, the same duplications that can lead to autism may also create what Eichler calls genetic "nurseries" in which new gene variants arise that enhance cognition or some other human trait.

"The evolutionary twist on this whole story," says Eichler, "is that our genome is really set up to fail, in the sense that we're prone to delete and duplicate. The flip side of it is that that selective disadvantage is offset by the emergence of novel genes that have conferred an advantage to us cognitively."

Diagnosing Hope

Despite the recent advances in autism genetics, there hasn't been much difference at the treatment level. Thomas Insel, director of the National Institute of Mental Health, put the new findings in perspective in an interview with a reporter from the Simons Foundation at the Society for Neuroscience meeting last November. "This has been an incredible period of discovery," said Insel, "but families are looking for interventions, not papers."

As genetic researchers identify more genes involved in autism, they are beginning to classify autism cases according to their association with particular mutations. Eichler's team, for example, recently gathered a group of patients with a mutation in the *CHD8* gene. And "lo and behold," Eichler says, the individuals shared many symptoms: 73 percent, for example, had severe gastrointestinal problems (*CHD8*, the researchers subsequently discovered, is also active in the gut). Such findings may in turn point to gene-specific interventions someday. The long-range hope is that as more rare mutations associated with autism are uncovered, the affected genes will tend to converge in ways that suggest molecular pathways critical to neurological development and function.

Researchers are quick to point out that de novo mutations are only part of the autism story. Scientists continue to hunt for inherited mutations and common variations that may also play important roles. But by using de novo mutations to spotlight some of the genes involved, Wigler and others have provided renewed hope for the field.

Indeed, though Wigler concedes that there is "a long way to go" before genetic findings translate into useful medicines, he sees therapeutic possibilities in the very nature of those mutations. "Because the kids that have autism have one bad gene and one good gene, I think there should be ways of getting that good gene to be more active, and probably reversing things," he says.

The genetic findings also suggest that even more dramatic (and ethically provocative) forms of therapy may be possible in the more distant future. "For many of the genes that we now think are important for autism, the genes are essentially [active] at eight to 16 weeks of development," says Eichler. "So you have to not only make a diagnosis early, but some people argue that you have to intervene early in order to make a big difference." And because many of the genes in question are also related to intelligence, Wigler says, it will be tempting to harness emerging technologies like prenatal genome analysis and precise new gene-editing tools as part of broader interventions in cognitive development. "It's a little dangerous to tap into it," he adds, "because we're getting to designer babies and the *Gattaca* world. The autism world does bring us face to face with some science fiction stuff."

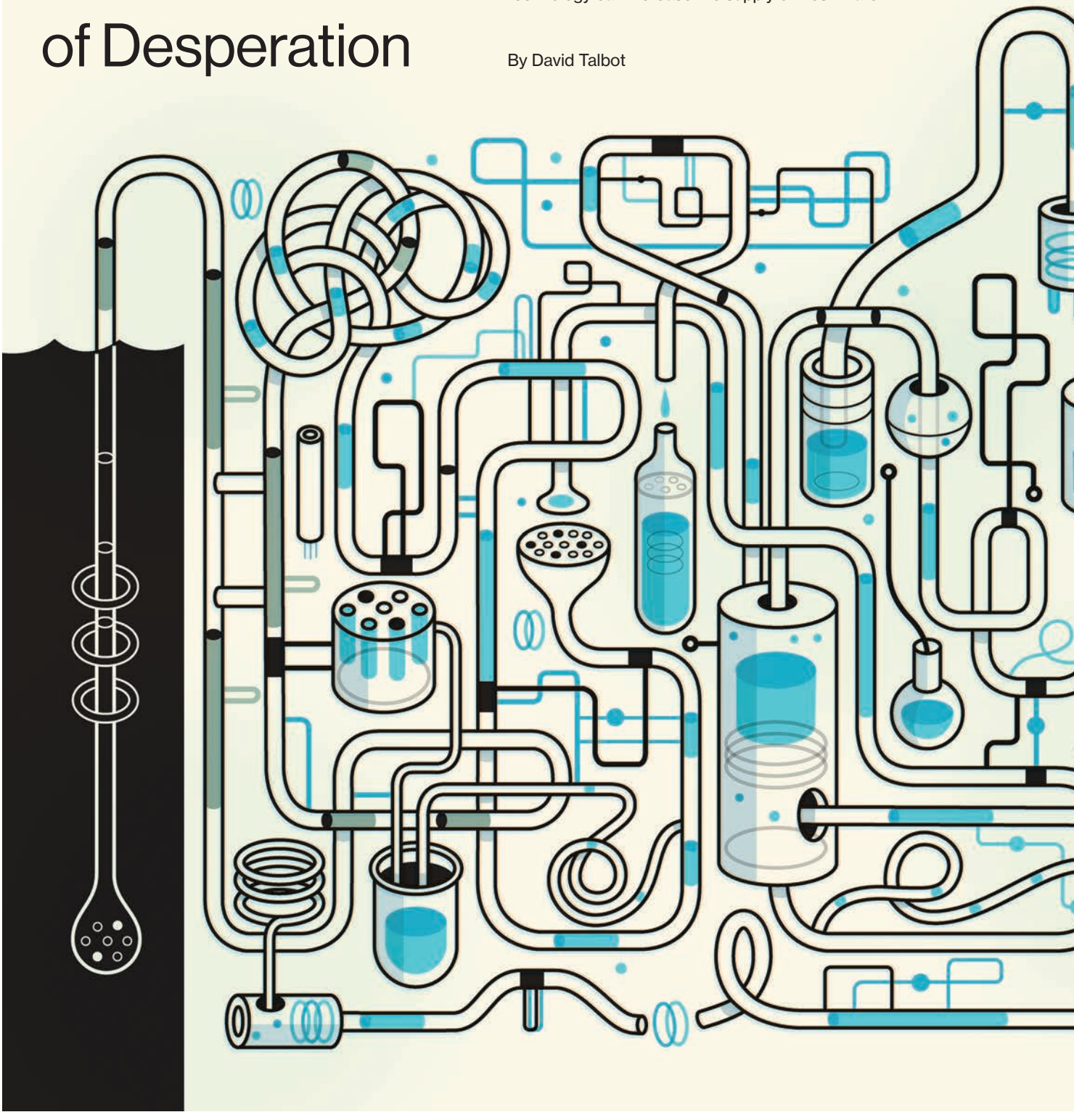
As urgently as Wigler wants to understand the puzzle of autism, even he abides by certain limitations on his curiosity. Asked if he had ever been tempted to reconnect with David, the autistic boy who inspired his original interest in the disease, he practically recoiled. "No," he said quickly. "That would be intruding." But he still can't stop talking about his old girlfriend's brother with something like awe. "It wasn't like he was trying to be different, you know? He wasn't," he said. "If anything, he was probably doing the opposite. But he was just really different. And it was an amazing thing." T

Stephen S. Hall, a science writer based in New York, teaches science communication and journalism at New York University. His last story for MIT Technology Review *was "Neuroscience's New Toolbox," in July/August 2014.*

Desalination out of Desperation

Severe droughts are forcing researchers to rethink how technology can increase the supply of fresh water.

By David Talbot



HARRY CAMPBELL

Even in drought-stricken California, San Diego stands out. It gets less rain than parched Los Angeles or Fresno. The region has less groundwater than many other parts of the state. And more than 80 percent of water for homes and businesses is imported from sources that are increasingly stressed. The Colorado River is so overtaxed that it rarely reaches the sea; water originating in the Sacramento River delta, more than 400 miles north, was rationed by state officials this year, cutting off some farmers in California's Central Valley from their main source of irrigation. San Diego County, hot, dry, and increasingly populous, offers a preview of where much of the world is headed. So too does a recent decision by the county government: it is building the largest seawater desalination plant in the Western Hemisphere, at a cost of $1 billion.

The massive project, in Carlsbad, teems with nearly 500 workers in yellow hard hats. When it's done next year, it will take in more than 100 million gallons of Pacific Ocean water daily and produce 54 million gallons of fresh, drinkable water. While this adds up to just 10 percent of the county's water delivery needs, it will, crucially, be reliable and drought-proof—a hedge against potentially worse times ahead.

The county is betting on a combination of modern engineering and decades-old desalination technology. A pipe trench under construction leads to a nearby lagoon inlet; 18 house-size concrete tanks await loads of sand and charcoal to treat the salt water before it is ready for desalination; pressurizers lead to a stainless-steel pipe one meter in diameter. This final piece of gleaming hardware will convey water under high pressure into 2,000 fiberglass tubes, where it will be squeezed through semipermeable polymer membranes. What gets through will be fresh water, leaving brine behind.

The process is called reverse osmosis (RO), and it's the mainstay of large-scale desalination facilities around the world. As water is forced through the membrane, the polymer allows the water molecules to pass while blocking the salts and other inorganic impurities. Global desalination output has tripled since 2000: 16,000 plants are up and running around the world, and the pace of construction is expected to increase while the technology continues to improve. Carlsbad, for example, has been outfitted with state-of-the art commercial membranes and advanced pressure-recovery systems. But the plants remain costly to build and operate.

Seawater desalination, in fact, is one of the most expensive sources of fresh water. The water sells—depending on site conditions—for between $1,000 and $2,500 per acre-foot (the amount used by two five-person U.S. households per year). Carlsbad's product will sell for around $2,000, which is 80 percent more than the county pays for treated water from outside the area. One reason is the huge amount of energy required to push water through the membranes. And Carlsbad, like most desalination plants, is being built with extra pumps, treatment capacity, and membrane tubes, the better to guarantee uptime.

"Because it is a critical asset for the region, there is a tremendous amount of redundancy to give high reliability," says Jonathan Loveland, vice president at Poseidon Water, the owner of the plant. "If any piece fails, something else will pick up the slack."

Already, some 700 million people worldwide suffer from water scarcity, but that number is expected to swell to 1.8 billion in just 10 years. Some countries, like Israel, already rely heavily on desalination; more will follow suit. In many places, "we are already at the limit of renewable water resources, and yet we continue to grow," says John Lienhard, a mechanical engineer and director of the Center for Clean Water and Clean Energy at MIT. "On top of that we have global warming, with hotter and drier conditions in many areas, which will potentially further reduce the amount of renewable water available." While conservation and recycling will help, you can't recycle what you don't have. "As coastal cities grow," he says, "the value of seawater desalination is going to increase rapidly, and it's likely we will see widespread adoption."

Against this grim backdrop, there is some good news. In short, desalination is ripe for technological improvement. A combination of sensor-driven optimization and automation, plus new types of membranes, could eventually allow for desalination plants that are half the size and use commensurately less energy. Among other benefits, small, mobile desalination units could be used in agricultural regions hundreds of miles away from the ocean, where demand for water is great and growing.

Smart Water

Every two weeks, Yoram Cohen, a chemical engineer who heads the Water Technology Research Center at the University of California, Los Angeles, hits the road for the drought-blasted San Joaquin Valley. Part of the state's vast agricultural midsection that grows much of the country's produce, the region has suffered badly. Last year, 2014, was the third straight drought year—at a time when demand for water has reached an all-time high. I joined Cohen for a recent outing: a car ride from his labs at UCLA to the small valley town of Firebaugh, in one of the hardest-hit agricultural regions in the state. Along I-5, the highway that connects the cities of California's southern coast with its central valley, we saw vast water-engineering edifices built in the 1950s, including four vast pipes traversing the Tehachapi Mountains and the cement-lined California Aqueduct, which cuts a serpentine path through the valley floor. The state's water system—devoted roughly 80 percent to agriculture and 20 percent to cities—is still conveying water pumped all the way from the Sacramento River delta through the 444-mile California Aqueduct. The water infrastructure made Southern California what it is today.

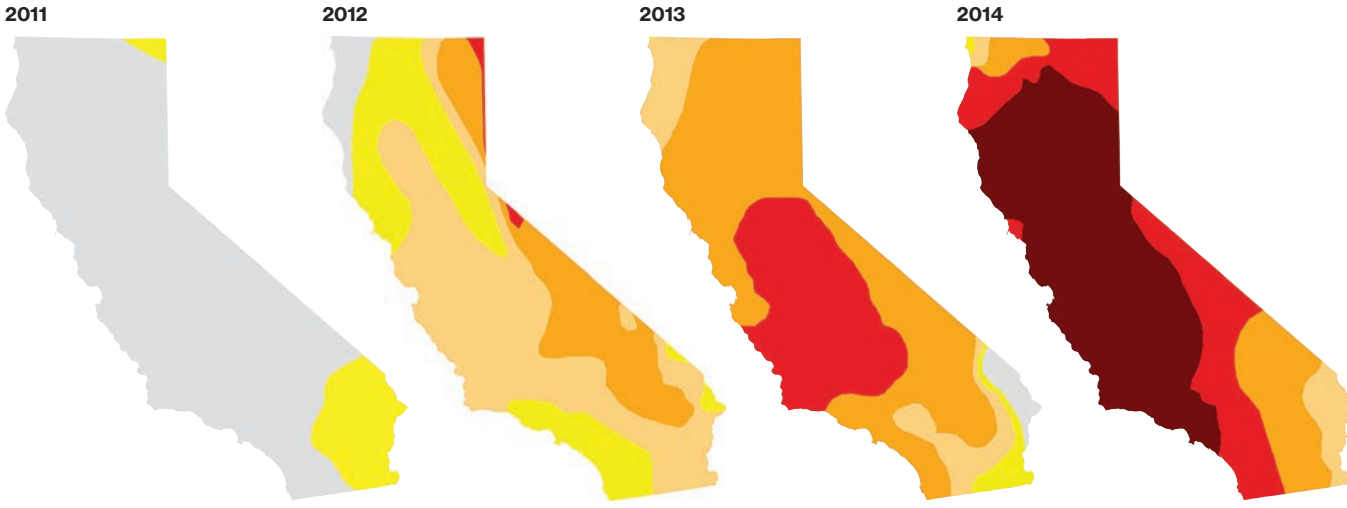
But it's a system under great stress. California's persistent lack of precipitation means 80 percent of the state is now in "extreme" or "exceptional" drought, forcing water restrictions in urban areas and cutoffs to some farmers. The results are plain to see: tracts of parched farmland lie newly abandoned; road signs flash warnings of "extreme drought"; signs plead "Water = Jobs." According to a recent study by the University of California, Davis, the drought inflicted $1.5 billion in agricultural losses in 2014 alone.

The Israeli-born Cohen explains that despite these pressures, desalination hasn't fundamentally changed since the 1980s. The time it takes to plan for big projects (Carlsbad took 14 years) makes it hard for investors to expect much payoff from new technologies, and U.S. federal research funding has gone to other priorities. Besides, it's been possible to recycle or conserve water so that expensive desalination has been less necessary. The flip side of this, Cohen says, is that desalination is now in a position to be transformed by the same kinds of sensing, automation, and algorithm-controlled processes that are remaking other industries. I would soon see what he was talking about.

As the late-October sun set, long shadows cast the crusty ground in high relief. We exited I-5, drove nine miles, and turned right on a hard-packed dirt lane between pistachio trees. It was dusk, and the beams from headlights disappeared into the flat desert nothingness. Yet when I opened the window, I caught a whiff of something that smelled vaguely like the salty air at the coast. The headlights exposed the culprit: a pipe vomiting a brew of much-reused agricultural runoff. It had started in the Sacramento delta as fresh water. But it got progressively more concentrated by evaporation in the aqueduct system, and still more so as it was applied to crops, picked up minerals in the ground, and was applied to crops again. It was now almost as saline as seawater, and contaminated with a range of minerals and fertilizers as well.

Cohen led me to a nearby trailer inhabited by two graduate students and a vast collection of tanks, pipes, valves, tubes, and computers. It was a totally automated system, able to use any of the brackish or polluted stuff Firebaugh's farmers produce and generate 30,000 drinkable gallons per day. A computer screen displayed a real-time black-and-white image that looked like a lunar landscape. It was a shot from a piece of the polyamide membrane at the center of the process. The image revealed a few white chunks: the beginning of mineral scaling, a bane of membranes. Image analysis software can detect this happening, and an algorithm can direct a valve to open and dispense an anti-scaling solution into the system—keeping ahead of the problem. Other sensors and control systems can drive tweaks to avert other fouling problems, changing the pressure or the dosage of chemical additives used for pretreatment.

State of Drought



The drought in California has been an important factor prompting a reconsideration of the need for seawater desalination. Though the state frequently lacks precipitation, a recent estimate suggests that the 2012–2014 drought is the worst in 1,200 years. Research by the University of Minnesota and the Woods Hole Oceanographic Institution examined the tree rings from ancient blue oaks to calculate the historical severity of today's drought.

Still under construction, the desalination plant in Carlsbad, California, will be the largest such facility in the United States. Awaiting installation at the facility are stainless-steel turbine pumps, wrapped in protective Mylar, that will be used to pump the clean water.

Energy required by existing plants to produce safe drinking water from various sources (kilowatt-hours per cubic meter).

DATA ON DROUGHT FROM THE NATIONAL DROUGHT MITIGATION CENTER. PHOTO BY DAVID TALBOT.
DATA ON ENERGY REQUIREMENTS FROM THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT 2014

Cohen reached for a plastic tube and twisted a small tap. Clear water drooled out; he held his hand out to capture some, lifted it to his mouth, drank a bit, and rubbed the rest on his face. "If we can figure out a car that does not require a driver, why can't we figure out how to run an RO plant without operators?" he said.

The savings could be significant: automated systems such as these could probably save between one-third and one-half the costs of conventional desalination plants, Cohen says. But more than that, a trailer-sized unit—able to adapt to different sites and conditions by the hour—could simply roll around and help farmers get fresh water no matter what they start with.

It takes a lot of energy to push water through the membranes.

Magic Membranes

Even if systems get smarter, reverse osmosis is still an energy hog. Carlsbad will consume more than 35 megawatts of electricity (which could power around 30,000 homes), for an annual bill of $30 million. About two-thirds of that will go to the water pressure needed to make the technology work. (The other third will go mostly to pumping the water 10 miles uphill to a reservoir, as well as to pretreatment and intake pumping.) Carlsbad's owners estimate that the plant will consume 2.8 kilowatt-hours per cubic meter for desalination alone. Some small reverse-osmosis systems, using differently configured processes (running water in batches rather than pumping continuously), are hitting 1.5 to 1.7 kilowatt-hours, says Lienhard. But the technology hasn't been proved at larger scales.

What's the problem? It takes a lot of work to push water through the membranes—pressure that translates into high energy usage. Those relatively thick polyamide membranes, though far from ideal, are the best we've got right now. But a few groups are trying to come up with more efficient materials. At MIT, mechanical engineer Rohit Karnik's team is building membranes a single atom thick, to help water molecules just pop through. The researchers blast graphene with ion beams and bathe it in chemicals to etch pores less than a nanometer across.

In theory, an essentially two-dimensional membrane like this one provides the least possible resistance. Computer models by Jeffrey Grossman's materials science and engineering group at MIT showed that graphene membranes could cut the energy used in reverse osmosis by 15 to 46 percent. Even better, the high permeability could mean that far less surface area is needed to get the job done, so the entire plant could be half the size.

So far Karnik has fabricated a one-square-centimeter graphene membrane, punched holes in it, and shown that it can selectively hold back certain ions. But he's not yet shown it can actually desalinate seawater, even on a lab bench. And once he or another group achieves that, the next challenge is to reliably make miles of membrane materials with consistent features. Karnik is optimistic that he'll get there, but he says it will be years before graphene membranes are ready.

Existing membrane materials might get better thanks to other nanoengineering approaches. In a small section of the Firebaugh trailer, Cohen is running an experiment with a membrane of his group's own devising. A base layer is made of polyamide. But then he adds a layer of tentacle-like brushes made of polymers that are hydrophilic, which means they attract water. Early research suggests these hybrid membranes may be far better at resisting fouling, because the brushes—which he likens to kelp swaying on an undersea rock—discourage things from sticking. This could mean less downtime, fewer replacements, and faster throughput. But Cohen, taking a swig of his ditch water, urges realism. "People have this fixation that somehow there will be a magic membrane that will reduce the cost of desalination to next to none, and I think that is a little bit misleading," he says.

For now in California's coastal municipalities, seawater is still the option of last resort, after conservation, recycling, and even treating and reusing sewage. While many are weighing desalination, the city most likely to follow in San Diego's footsteps is Santa Barbara. That's because it already built an RO plant in the early 1990s after a five-year drought, only to quickly shut it down when a couple of years of good winter rains refilled reservoirs. The city recently moved to start funding an expensive rehabilitation of the site so that it can be reactivated if needed. Other municipalities have decided it's too expensive or environmentally problematic (the facilities inevitably kill fish eggs and other marine life, unless intake pipes are buried beneath sand at great cost).

But that assessment might get turned on its head. Water captured in reservoirs or pumped from faraway deltas is getting more expensive—and such alternatives come with their own environmental costs. As sources dry up and competition for water mounts from businesses, farmers, and cities, we will inevitably turn to seawater and other salty sources. It might not be a great solution, but the bottom line is that we are left with fewer and fewer choices in a water-starved world. T

David Talbot is chief correspondent for MIT Technology Review.

MIT Technology Review

EmTech DIGITAL

MIT Technology Review subscribers **SAVE 15%.** Use code ***TRSub*** at registration.

Innovations and Ideas Fueling Our Connected World

June 1–2, 2015 San Francisco, CA St. Regis Hotel

Featured topics:

- **Digital Life** The lines between our online and offline lives are blurred as everything around us becomes connected. The implications are profound. How will our health benefit as new devices track every heartbeat, movement, breath–even mood?
- **Digital Work** Cloud, big data and mobile – Silicon Valley's enduring trends – have truly impacted our daily lives. How will brands engage and influence us in the future? How will we pay for their products and services? How will security and privacy evolve?
- **Digital Play** A new generation of devices and experiences promise to reinvent entertainment. Connected consumers are driving a renaissance in digital content and design.

Questions? Please e-mail: eventsreg@technologyreview.com

REGISTER BY MARCH 1 AND SAVE $500: technologyreview.com/EmTechDigital

MIT TECHNOLOGY REVIEW
VOL. 118 | NO. 1

Journalists and researchers wade into ugly corners of the Internet to expose racists, thugs, and bullies. Have they gone too far?

By Adrian Chen

The Troll Hunters

We've come up with the menacing term "troll" for someone who spreads hate and does other horrible things anonymously on the Internet. Internet trolls are unsettling not just because of the things they say but for the mystery they represent: what kind of person could be so vile? One afternoon this fall, the Swedish journalist Robert Aschberg sat on a patio outside a drab apartment building in a suburb of Stockholm, face to face with an Internet troll, trying to answer this question. The troll turned out to be a quiet, skinny man in his 30s, wearing a hoodie and a dirty baseball cap—a sorry foil to Aschberg's smart suit jacket, gleaming bald head, and TV-trained baritone. Aschberg's research team had linked the man to a months-long campaign of harassment against a teenage girl born with a shrunken hand. After meeting her online, the troll tormented her obsessively, leaving insulting comments about her hand on her Instagram page, barraging her with Facebook messages, even sending her taunts through the mail.

Aschberg had come to the man's home with a television crew to confront him, but now he denied everything. "Have you regretted what you've done?" Aschberg asked, handing the man a page

Martin Fredriksson in a Stockholm underground station in November. Photographs by Anders Lindén.

of Facebook messages the victim had received from an account linked to him. The man shook his head. "I haven't written anything," he said. "I didn't have a profile then. It was hacked."

This was the first time Aschberg had encountered an outright denial since he had started exposing Internet trolls on his television show *Trolljägarna* (*Troll Hunter*). Usually he just shoots them his signature glare—honed over decades as a muckraking TV journalist and famous for its ability to bore right through sex creeps, stalkers, and corrupt politicians—and they spill their guts. But the glare had met its match. After 10 minutes of fruitless back and forth on the patio, Aschberg ended the interview. "Some advice from someone who's been around for a while," he said wearily. "Lay low on the Internet with this sort of stuff." The man still shook his head: "But I haven't done any of that."

"He's a pathological liar," Aschberg grumbled in the car afterward. But he wasn't particularly concerned. The goal of *Troll Hunter* is not to rid the Internet of every troll. "The agenda is to raise hell about all the hate on the Net," he says. "To start a discussion." Back at the *Troll Hunter* office, a whiteboard organized Aschberg's agenda. Dossiers on other trolls were tacked up in two rows: a pair of teens who anonymously slander their high school classmates on Instagram, a politician who runs a racist website, a male law student who stole the identity of a young woman to entice another man into an online relationship. In a sign of the issue's resonance in Sweden, a pithy neologism has been coined to encompass all these forms of online nastiness: *näthat* ("Net hate"). *Troll Hunter*, which has become a minor hit for its brash tackling of *näthat*, is currently filming its second season.

Hate is having a sort of renaissance online, even in the countries thought to be beyond it.

It is generally no longer acceptable in public life to hurl slurs at women or minorities, to rally around the idea that some humans are inherently worth less than others, or to terrorize vulnerable people. But old-school hate is having a sort of renaissance online, and in the countries thought to be furthest beyond it. The anonymity provided by the Internet fosters communities where people can feed on each other's hate without consequence. They can easily form into mobs and terrify victims. Individual trolls can hide behind dozens of screen names to multiply their effect. And attempts to curb online hate must always contend with the long-standing ideals that imagine the Internet's main purpose as offering unfettered space for free speech and marginalized ideas. The struggle against hate online is so urgent and difficult that the law professor Danielle Citron, in her new book *Hate Crimes in Cyberspace,* calls the Internet "the next battleground for civil rights."

That Sweden has so much hate to combat is surprising. It's developed a reputation not only as a bastion of liberalism and feminism but as a sort of digital utopia, where Nordic geeks while away long winter nights sharing movies and music over impossibly fast broadband connections. Sweden boasts a 95 percent Internet penetration rate, the fourth-highest in the world, according to the International Telecommunication Union. Its thriving tech industry has produced iconic brands like Spotify and Minecraft. A political movement born in Sweden, the Pirate Party, is based on the idea that the Internet is a force for peace and prosperity. But Sweden's Internet also has a disturbing underbelly. It burst into view with the so-called "Instagram riot" of 2012, when hundreds of angry teenagers descended on a Gothenburg high school, calling for the head of a girl who spread sexual slander about fellow students on Instagram. The more banal everyday harassment faced by women on the Internet was documented in a much-discussed 2013 TV special called *Men Who Net Hate Women*, a play on the Swedish title of the first book of Stieg Larsson's blockbuster Millennium trilogy.

Internet hatred is a problem anywhere a significant part of life is lived online. But the problem is sharpened by Sweden's cultural and legal commitment to free expression, according to Mårten Schultz, a law professor at Stockholm University and a regular guest on *Troll Hunter*, where he discusses the legal issues surrounding each case. Swedes tend to approach *näthat* as the unpleasant but unavoidable side effect of having the liberty to say what you wish. Proposed legislation to combat online harassment is met with strong resistance from free speech and Internet rights activists.

What's more, Sweden's liberal freedom-of-information laws offer easy access to personal information about nearly anyone, including people's personal identity numbers, their addresses, even their taxable income. That can make online harassment uniquely invasive. "The government publicly disseminates a lot of information you wouldn't be able to get outside of Scandinavia," Schultz says. "We have quite weak protection of privacy in Sweden."

Yet the rich information ecosystem that empowers Internet trolls also makes Sweden a perfect stalking ground for those who want to expose them. In addition to Aschberg, a group of volunteer researchers called *Researchgruppen*, or Research Group, has pioneered a form of activist journalism based on following the crumbs of data anonymous Internet trolls leave behind and unmasking them. In its largest troll hunt, Research Group scraped the comments section of the right-wing online publication Avpixlat and obtained a huge database of its comments and user information. Starting with this data, members meticulously identified many of Avpixlat's most prolific commenters and then turned the names over to *Expressen*, one of Sweden's two major tabloids. In December 2013, *Expressen* revealed in a series of front-page stories that dozens of prominent Swedes had posted racist, sexist, and otherwise hateful comments under pseudonyms on Avpixlat, including a number of politicians and officials from the ascendant far-right Sweden Democrats. It was one of the biggest scoops of the year. The Sweden Democrats, which have their roots in Sweden's neo-Nazi movement, have long attempted to distance themselves from their racist past, adopting a more respectable rhetoric of protecting "Swedish culture." But here were their members and supporters casting doubt on the Holocaust and calling Muslim immigrants "locusts." A number of politicians and officials were forced to resign. *Expressen* released a short documentary of its reporters acting as troll hunters, knocking on doors and confronting Avpixlat commenters with their own words.

The same information ecosystem that aids trolls also makes it easier to expose them.

Make the Unknown Known

Martin Fredriksson is a cofounder of Research Group and its de facto leader. He is a lanky 34-year-old with close-cropped hair and a quietly intense demeanor, though he is prone to outbursts on Twitter that hint at his past as a militant anti-racism activist. I met Fredriksson at the tiny one-room office of Piscatus, the public records service for journalists that he oversees as his day job. Robert Aschberg, the chair of Piscatus's board, has known Fredriksson for years and jokes that he is a brilliant researcher and an excellent journalist, but "you can't have him in furnished rooms." The extreme sparseness of the office bore him out. One of the only decorations was a Spice Girls poster.

Fredriksson hunched over his computer's dual screens and logged in to the intranet he had created to coördinate Research Group's unmasking of Avpixlat users. Research Group typically works in a decentralized manner, with members pursuing their own projects and collaborating with others when needed. The group currently has 10 members, all volunteers, including a psychology graduate student, a couple of journalism students, a grade school librarian, a writer for an online IT trade publication, and a porter in a hospital. The little organizing that occurs typically happens in Internet relay chat rooms and on a wiki. But analyzing the Avpixlat database, which contained three million comments and over 55,000 accounts, required a centralized, systematized process. An image on the main page of the intranet pokes fun at the immensity of the task. Two horses have their heads stuck in a haystack. "Find anything?" asks one. "Nope," says the other.

Research Group was founded during the exhaustive process of unmasking a particularly frightening Internet troll. That episode began in 2005, when Fredriksson and his close friend Mathias Wåg learned that an anonymous person was requesting public information about Wåg from the government. As a return address, the requester used a post office box in Stockholm. That kept Fredriksson and Wåg in the dark at first. But the next year, they obtained a copy of a prison magazine in which a notorious neo-Nazi named Hampus Hellekant, who was in prison for murdering a union organizer, had listed the same post office box. In 2007, after Hellekant was released, pseudonymous posts began to appear on Swedish neo-Nazi forums and websites, soliciting information about Wåg and other leftist activists.

For three years, Fredriksson and some like-minded investigators tracked Hellekant's every move, online and off. "He was functioning more or less as the intelligence service for the Nazi movement," Fredriksson says. Their counterintelligence operation involved a mix of traditional journalistic techniques and innovative data analysis. One unlikely breakthrough came courtesy of Hellekant's habit of illegally parking his car all over Stockholm. Fredriksson's team requested parking ticket records from the city. They were able to match the car's location on certain days with time and GPS metadata on image files Hellekant posted under a pseudonym. In 2009 they sold the story of Hellekant's post-prison activities to a leftist newspaper, and Research Group was born.

Since then, its members have investigated the men's rights movement, Swedish police tactics, and various right-wing groups. Until the Avpixlat story they had mostly published their findings quietly on their website or partnered with small left-wing news organizations. "The official story is that we pick subjects about democracy and equality," says Fredriksson. "But the real reason is that we just have special interests—we just try to focus on stuff that interests us as people."

By the time Research Group came together, Fredriksson's interest in Nazi hunting and talent for investigative reporting had landed him a job with Aschberg. Fredriksson had scraped data from a mobile payment platform with woefully inadequate security in order to investigate the donors to a neo-Nazi website. He also happened to get the records of scores of users who had made payments to Internet porn sites. Aschberg used the data on his show *Insider,* Sweden's answer to NBC's *Dateline*, where he exposed government officials who had bought Internet porn on their official cell phones. Then he hired Fredriksson as a researcher on *Insider*: he functioned as the technical brains behind many of Aschberg's confrontations. Today Fredriksson does not work for *Troll Hunter*, and the show has no formal connection to Research Group. But Fredriksson's legacy is clear in the technical detective work that the show often uses to expose its targets.

Fredriksson might accurately be called a "data journalist," as his specialty is teasing stories from huge spools of information. But the bland term doesn't do justice to his guerrilla methods, which can make the pursuit of information as thrilling as the hunt for a serial killer in a crime novel. When Fredriksson gets interested in a project, he seizes it obsessively. Aschberg speaks of him in awe, as a potent but alien force. "He's very special," he says. "He's one of those guys who can sit for 24 hours and drink sodas and just work."

Fredriksson is a member of a generation of Swedes known as "Generation 64," who grew up tinkering with Commodore 64s in the 1980s and went on to revolutionize Sweden's IT industry. His upbringing also coincided with the rise of a neo-Nazi movement in the 1990s, when he was a teenage punk rocker. He and his friends constantly clashed with a gang of skinheads in his small hometown in southern Sweden. "I was very interested in politics. I came to the conclusion that if I wanted to do politics I'd have to deal with the Nazi threat in some way," he says. He joined the controversial leftist group Antifascistisk Aktion (AFA), which openly endorses the use of violence against neo-Nazis. In 2006 he was sentenced to community service for beating a man during a fight between a group of neo-Nazis and antiracists. "He said it was me. It actually wasn't, but it just as well could have been," Fredriksson says. He says he eventually came to believe that violence is wrong, and today his weapon of choice is information, not his fists. He is more interested in understanding hate than destroying it, although he wouldn't mind if one led to the other. Research Group challenges the traditional divide between activism and journalism: it is guided by the values of its members, many of whom come from leftist circles. In the early 2000s, Fredriksson was heavily involved in Sweden's free culture movement, which abhorred copyright laws, embraced piracy, and coded the first version of the legendary Pirate Bay's BitTorrent tracker. Whenever Research Group is in the news, critics seize on its members' leftist ties to discredit them as agenda-driven propagandists. But their methods are meticulous, and their facts are undeniable. "Our history will always be there," says Fredriksson. "People will always say, 'Oh, 10 years ago you did that.' Whereas I live in the now. The only way for me to build credibility is to just publish valid stuff again and again, and hope I'm not wrong."

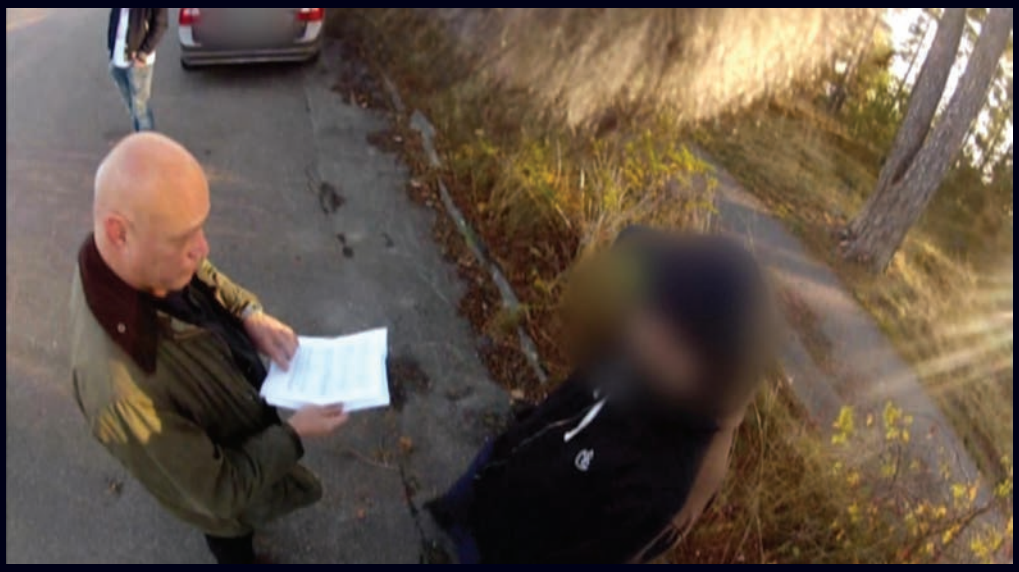
However, his idiosyncratic background sometimes leads him from the path of traditional journalistic inquiry into murky ethical territory. "I like to pick up stones and see what's under them," he says. "I like to go wherever I want to go and just look at stuff."

The mass unmasking of Avpixlat commenters in 2013 was an accidental consequence of this curiosity. Avpixlat is an influential voice in Sweden's growing right-wing populist movement, which is driven by a xenophobic panic that Muslim immigrants and Roma are destroying the country. The site fixates on spreading stories of rapes and murders committed by immigrants, which it contends are being covered up by the liberal establishment. ("Avpixlat" means "de-pixelate," as in un-censoring an image that's been digitally obscured.) Initially, Fredriksson wanted to study how it functioned as a source of *näthat*. Avpixlat, and especially its unruly comments section, has become notorious as a launching pad for rampaging online mobs. "They provoke, they incite people to harass politicians and journalists," says Annika Hamrud, a journalist who has written extensively about the Swedish right wing. When the site picked up the story of how a shop owner in a small town put up a sign welcoming Syrian refugees to Sweden, she explains, he was bombarded with online abuse. Wåg, Fredriksson's friend and colleague, calls Avpixlat "the finger that points the mob where to go." Fredriksson's idea was to create a database of Avpixlat comments in order to investigate how its cybermobs mobilized. Avpixlat uses the popular commenting platform Disqus, which is also used by mainstream publications in Sweden and around the world. Fredriksson planned to scrape Disqus comments from Avpixlat and as

EXPRESSEN.SE; IMAGES 2 AND 5 COURTESY OF RESEARCH GROUP; IMAGES 3 AND 4 COURTESY OF DRG TV STRIX

1.

2.



3.

1. The Expressen *home page when the paper published the Avpixlat scoop, unmasking prominent Swedes.*

2. Members of Research Group.

3. With evidence in hand, Aschberg confronts a troll on his show.

4. A publicity shot for Troll Hunter.

5. A neo-Nazi rally in Linköping, Sweden, in 2005.

4.

5.

many other Swedish websites as possible. He would then compare the handles of commenters on mainstream websites with those on Avpixlat. The extent of the overlap would suggest how dominant Avpixlat users were throughout the Web, and how responsible they were for the general proliferation of *näthat*.

Fredriksson hacked together a simple script and began to scrape Avpixlat's comments using Disqus's public API (the application programming interface, which lets online services share data). As he built his database, he noticed something odd. Along with each username and its associated comments, he was capturing a string of encrypted data. He recognized the string as the result of a cryptographic function known as an MD5 hash, which had been applied to every e-mail address that commenters used to register their accounts. (The e-mail addresses were included to support a third-party service called Gravatar.) Fredriksson realized he could figure out Avpixlat commenters' e-mail addresses, even though they were encrypted, by applying the MD5 hash function to a list of known addresses and cross-referencing the results with the hashes in the Avpixlat database. He tested this theory on a comment he'd made on Avpixlat with his own Disqus account. He encrypted his e-mail address and searched the Avpixlat database for the resulting hash. He found his comment. "By that time I knew I had stumbled on something which the newspapers would be very interested in," he says. He kept his scrapers running on Avpixlat and other websites that used Disqus, including American sites like CNN, eventually assembling a database of 30 million comments. But the goal was no longer a general survey of *näthat*. He wanted to answer an even more fundamental question: who are the real people behind Avpixlat's hateful comments? "It had been like this great unknown for many years," Fredriksson says. "It was this huge blank spot on the map that we could just fill out. Make the unknown known."

In order to begin the process of unmasking Avpixlat's users, Research Group needed a huge list of e-mail addresses to check against the Avpixlat commenter database, especially those of people whose participation in a racist right-wing website would be newsworthy. Sweden's liberal public-records laws proved invaluable again. Research Group filed public information requests and collected thousands of e-mail addresses of parliament members, judges, and other government officials. For good measure, Fredriksson threw in a list of a few million e-mail addresses he'd found floating around on the Web. All told, Research Group assembled a list of more than 200 million addresses—more than 20 times the population of Sweden—to check against the database of 55,000 Avpixlat accounts.

Fredriksson gives lectures about online research, and he has found it's easier to unmask people than many believe. "Anonymity online is possible, but it's frail," he says. He clicked on one Avpixlat user who had used his account to complain a lot about Muslims. He entered the user's e-mail address into Google and found that the man had listed the address and his full name on the roster of his local boating club: "There he is." If users' e-mail addresses didn't suffice, a researcher would begin wading through their comments, which sometimes numbered in the thousands, to glean clues to their identity.

Research Group toiled away for 10 months on the Avpixlat data, eventually identifying around 6,000 commenters, of whom only a handful were ever publicly named. A few months into the research, Fredriksson approached *Expressen*, whose investigative reporting on the Swedish far right he admired. The newspaper bought the story.

Payback

Research Group was so focused on analyzing the database that it did not seriously consider what the public fallout from the revelations might be. When the story came out, it sparked

Fredriksson says people who spread hatred don't deserve anonymity.

a firestorm. Angry Internet users, who saw the exposé as an assault on freedom of speech, began to distribute addresses of Research Group members as payback, a favored tactic of online intimidation known as "doxxing." A Research Group member named My Vingren moved from her apartment after strange men visited one night. The address of Fredriksson's parents was circulated. Debate about the ethics of the story raged, and even political opponents of the Sweden Democrats voiced reservations. Particularly egregious to some critics was that while many of *Expressen*'s targets were politicians, some were private citizens, including businesspeople and a professor. "I was this close to having a stress reaction," Fredriksson says.

"I like to pick up stones and see what's under them," Fredriksson says.

Fredriksson stands by Research Group's work on the database. He does not believe anonymity should be protected if it's used to spread hate. "I think there are legitimate causes for anonymity," he says. "But I think the Internet is a wonderful thing—I've been part of spreading culture among the masses—and personally, I get pissed off when the Internet is abused by some people." Still, he's ambivalent about *Expressen*'s exposure of private citizens. Research Group left it up to *Expressen* to choose what to report. If it had been his choice, he says, he would only have exposed politicians. "It could have been a much stronger story if they had stuck to public figures," he says.

Research Group emerged from the furor slightly shell-shocked but proud, with a newfound reputation as a reputable journalistic force. A few months later, the Swedish Association of Investigative Journalists gave the group and *Expressen* an award for the scoop. This past September, *Expressen* published a new series based on the data, exposing more Sweden Democrats. One had called a black man a chimpanzee, while another had suggested that Muslims were genetically predisposed to violence. For these stories, Research Group was nominated for the *Stora Journalistpriset,* Sweden's most prestigious journalism prize.

The stories came out a week before Sweden's general election and had, by all appearances, no effect on the outcome. In fact, the Sweden Democrats won 13 percent of the vote, doubling their previous result to become the third-largest party in Sweden. Some even suggested that *Expressen* had helped the Sweden Democrats by making them seem like victims. Fredriksson says he's simply happy to have helped push their public persona a little closer to what he believes they stand for in their heart of hearts: the ugly id that's visible in Avpixlat's comments sections every day. "I say, well, we just showed that they are racist, and people are apparently liking that," he says. "So, good for them."

Research Group is currently deep into researching its next project, which is based on a huge database belonging to Flashback, Sweden's largest general-interest forum. At a recent gathering, Research Group members spent six hours working through a list that Fredriksson provided of 100 e-mail addresses belonging to high-ranking military members, to see whether they had posted anything interesting on the site. They found only one—a man who had apparently confessed to hiring prostitutes, although this was unlikely to rise to the level of newsworthiness their publishing partner was looking for.

Exposing Flashback users could prove to be even more explosive than outing Avpixlat commenters. Flashback users do not talk mainly about their hatred of immigrants (though some do) but about their love lives, video games, cooking, politics, drug habits—the whole spectrum of human interest. Last summer, Fredriksson sparked an online outcry when someone asked on Twitter if Research Group had the database and he replied in the affirmative. When asked why, he brusquely responded, "Because we can."

The tweet was controversial even within Research Group, and Fredriksson later tried to clarify that the team would be mining the database for *näthat*. But many Flashback users probably weren't mollified. Research Group had "bragged about having stuff that would jeopardize vulnerable people's secrets," says Jack Werner, a journalist who covers online culture for the Swedish daily *Metro* and is a longtime Flashback user. "It was not very ethical but rather quite blunt and childish." Anna Troberg, the leader of Sweden's Pirate Party, denounced Research Group as "glorified vigilantes."

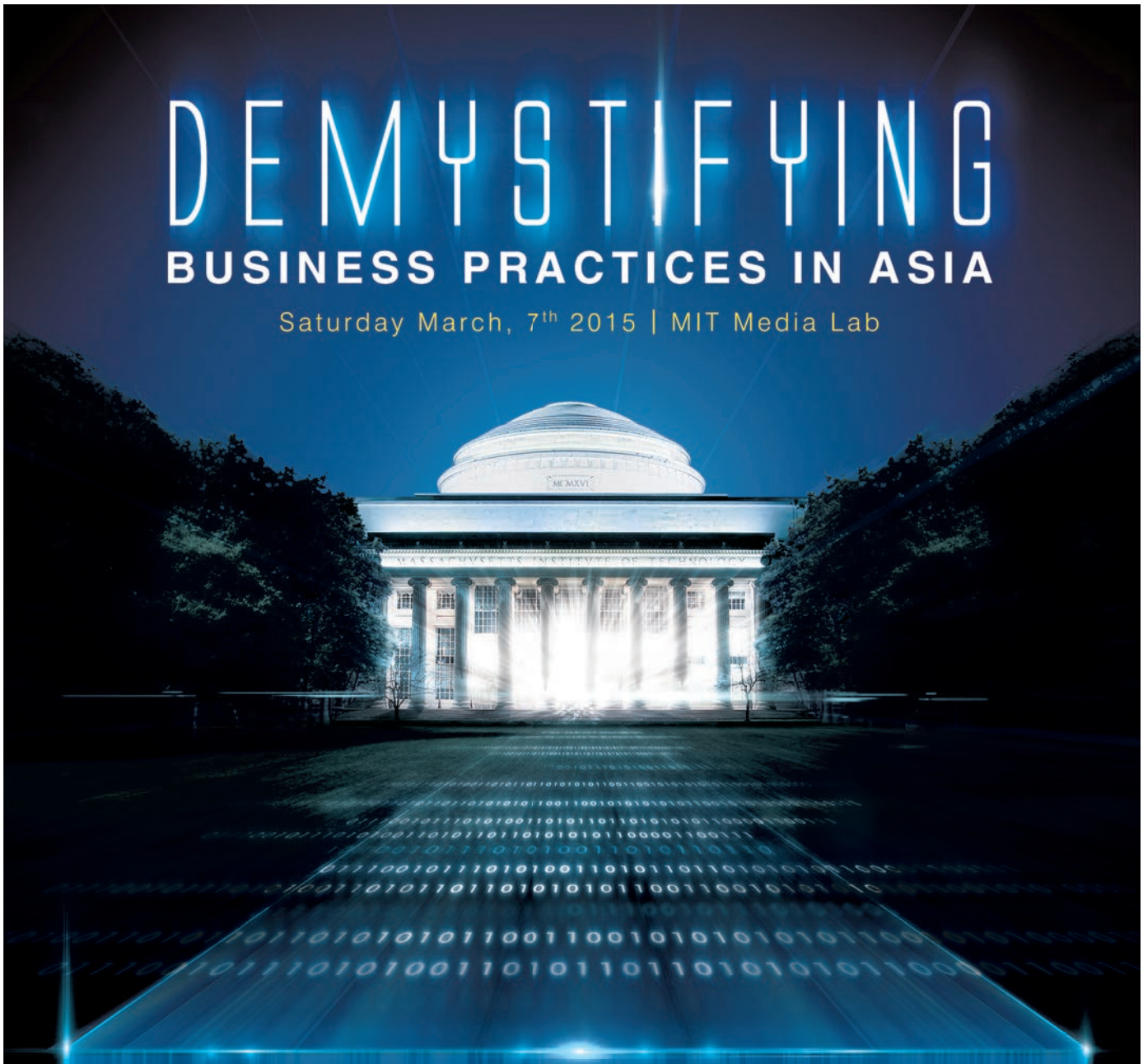
Fredriksson wouldn't tell me much about the project, except that it would be similar to the Avpixlat story in focusing mainly on official misdeeds. He says Flashback users can rest assured that Research Group is not interested in exposing anyone's medical issues. "If they posted in the sex or drugs or health sections, then it's just not interesting to us," he says. "If they post in other parts of Flashback, where they put up slander about other people? It's interesting to look at that."

Adrian Chen is a freelance writer whose work has appeared in New York, Wired, *and the* New York Times.

DEMYSTIFYING

BUSINESS PRACTICES IN ASIA

Saturday March, 7th 2015 | MIT Media Lab



MIT ASIA BUSINESS CONFERENCE 2015

A DEEP DIVE INTO TECHNOLOGY, MANUFACTURING AND FINANCE SECTORS

Please join us to meet with prominent industry leaders and to hear more about the extraordinary experiences that are shaping Asian businesses today

Visit us at : www.mitasiabusinessconference.com

Like us on Facebook : www.facebook.com/MITABConference

Massachusetts Institute of Technology

MIT ASIA BUSINESS CONFERENCE

BUSINESS REPORT

Cities Get Smarter

Urban centers will add 2.5 billion residents over the next 35 years. Can technology help them cope?

CONTENTS

The Big Question
Data-Toting Cops
Tianjin: China's Future City
Smart Cities Will Take Many Forms
Car Technology to Invigorate Cities
Booming Lagos, Smart City

Find additional material for this report at technologyreview.com/business

VIKTOR HACHMANG

The Big Question

Cities Find Rewards in Cheap Technologies

Mobile apps, sensors, and other technologies help cities handle growing challenges.

● Cities around the globe, whether rich or poor, are in the midst of a technology experiment. Urban planners are pulling data from inexpensive sensors mounted on traffic lights and park benches, and from mobile apps on citizens' smartphones, to analyze how their cities really operate. They hope the data will reveal how to run their cities better and improve urban life. City leaders and technology experts say that managing the growing challenges of cities well and affordably will be close to impossible without smart technology.

Fifty-four percent of humanity lives in urban centers, and almost all of the world's projected population growth over the next three decades will →

take place in cities, including many very poor cities. Because of their density and often-strained infrastructure, cities have an outsize impact on the environment, consuming two-thirds of the globe's energy and contributing a large share of its greenhouse-gas emissions. Urban water systems are leaky. Pollution levels are often extreme.

But cities also contribute most of the world's economic production. Thirty percent of the world's economy and most of its innovation are concentrated in just 100 cities. Can technology help manage rapid population expansion while also nurturing cities' all-important role as an economic driver? That's the big question at the heart of this Business Report.

Selling answers to that question has become a big business. IBM, Cisco, Hitachi, Siemens, and others have taken aim at this market, publicizing successful examples of cities that have used their technology to tackle the challenges of parking, traffic, transportation, weather, energy use, water management, and policing. Cities already spend a billion dollars a year on these systems, and that's expected to grow to $12 billion a year or more in the next 10 years.

To justify this kind of outlay, urban technologists will have to move past the test projects that dominate discussions today. Instead, they'll have to solve some of the profound and growing problems of urban living. Cities leaning in that direction are using various technologies to ease parking, measure traffic, and save water (see "Sensing Santander"), reduce rates of violent crime (see "Data-Toting Cops"), and prepare for ever more severe weather patterns.

There are lessons to be learned, too, from cities whose grandiose technological ideas have fallen short, like the eco-city initiative of Tianjin, China (see "China's Future City"), which has few residents despite great technology and deep government support.

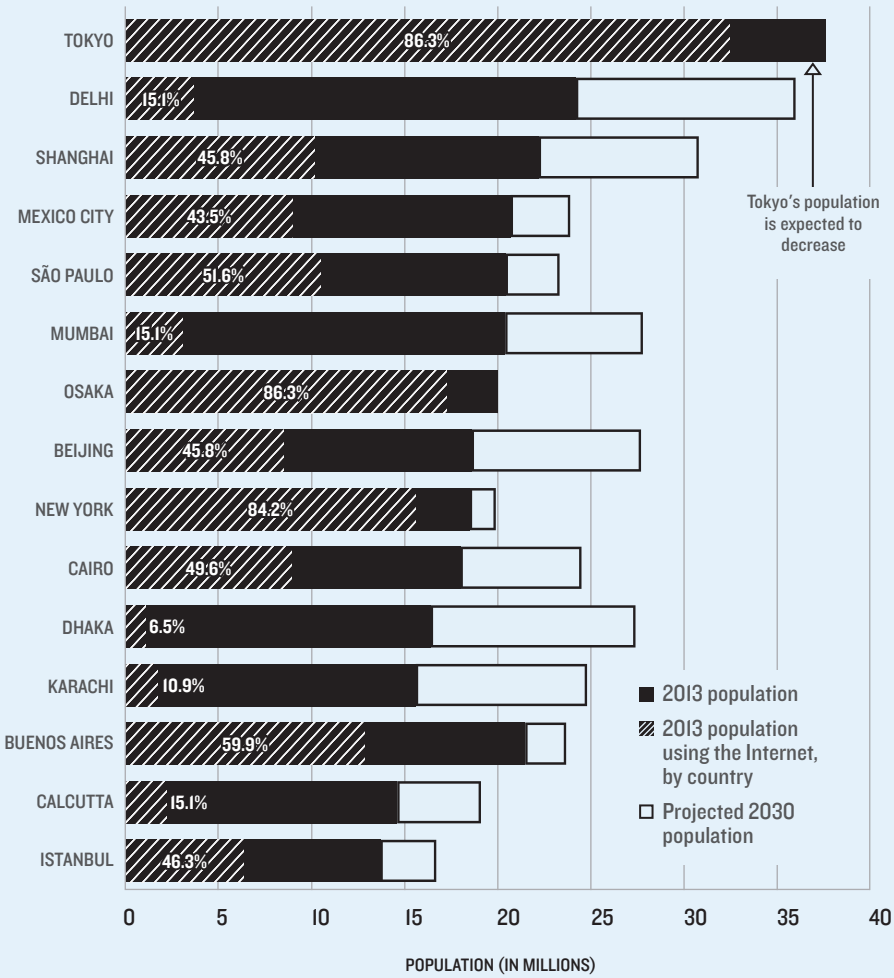
The streets are similarly largely empty in the experimental high-tech cities of Songdo, South Korea; Masdar City, Abu Dhabi; and Paredes, Portugal, which are being designed to have minimal impact on the environment and offer high-tech conveniences such as solar-powered air-conditioning and pneumatic waste disposal systems instead of garbage trucks. Meanwhile, established cities are taking a much more incremental, less ambitious, and perhaps more workable approach, often benefiting from relatively inexpensive and flexible digital technologies.

Since its launch in 2010, the Mayor's Office of New Urban Mechanics in Boston has focused on small-scale initiatives that exploit technology and data, aiming to pull people into a practice it calls "participatory urbanism."

The office's first project was Citizens Connect, a digital hotline that allows people to use their smartphones to report trash, graffiti, and service problems to City Hall. Since then the office has rolled out City Worker, which helps municipal employees track their daily tasks and report progress to their bosses and to citizens. Pilot programs are testing mobile parking ticket payments, smart parking meters, pothole reporting, and sensors in streets that would alert drivers to open parking spaces.

City Worker is the reason why, one sunny September afternoon, John Schallmo was taking a picture of an empty brick sidewalk on his Android phone. Schallmo, a 30-year Boston city employee, was in the brownstone-lined South End to document the cleanup of a pile of crumpled papers and plastic bags. The mess had been reported through Citizens Connect, and with the trash cleaned up, the

The Big Get Bigger
Mega-cities often lag technologically



SOURCES: UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS; INTERNATIONAL TELECOMMUNICATION UNION

photo evidence would be sent to the person who had notified the city, proof that he or she had made a difference. The photo would go, too, into a series of departmental maps tracking crew locations, pothole reports, and other problems.

Technology has had its failures in Boston. A text version of Citizens Connect was a dud. And registering potholes and trash may seem relatively mundane, even futile, in streets that are marred by broken pavement and litter. But Nigel Jacob and Chris Osgood, directors of the Office of New Urban Mechanics, say these small steps build greater trust between the public and government, creating a platform to take on bigger challenges in education and housing.

In the developing world, where most of the urban growth has come in recent years, mobile technologies offer a cost-effective way of managing environmental and civic challenges that figure to worsen (see "Booming Lagos, Smart City").

In India, where the urban population is predicted to increase from 31 percent of the total to 38 percent by 2026, Prime Minister Narendra Modi plans to invest $1.2 billion in 100 new and retrofitted smart cities. But in the western textile city of Surat, population five million, relatively inexpensive technology is making the greatest difference. A flood warning system uses temperature, rainfall, wind speed, and other data captured by new automated weather stations, combined with information from river gauges, satellites, and other sources, to create models of the nearby Tapti River and Ukai reservoir. It cost less than $500,000 to set up, plus some land donated by the city, but the system was able to warn citizens two days before floods struck during the 2013 rainy season, giving them time to buy groceries and drive to high ground. A second project, connecting health workers around the region to centralized data via the Internet and SMS, has helped the health department predict outbreaks of malaria, viral hepatitis, dengue fever, and leptospirosis and take action to prevent their spread.

Technology is not just a tool cities can use to manage their tremendous growth; it's a big part of what's driving it, too. Harvard economist Edward Glaeser, author of *The Triumph of the City,* argues that following a century of technological innovations that made distance less important, from the automobile to video games, technology has more recently begun to boost cities by creating a more "idea-intensive and complicated world." As social beings, we tackle these challenges especially well in close proximity to one another. Technology is "moving us toward an economy that very much rewards intelligence and innovation," says Glaeser, "and that moves us in the direction of urbanization."

—Nanette Byrnes

66%
Proportion of energy consumed by cities

Technologies

Data-Toting Cops

Twenty years after it first surfaced, data-driven police work is getting more pervasive but remains controversial.

● Mornings at 7:00, Wade Brabble has decisions to make. So in the last year, he has come to rely upon a computer-generated forecast of where crime will happen on his day shift as a police lieutenant in Fort Lauderdale, Florida. Depending on the report, which comes out of a system built in a year-old partnership with IBM, he'll move his 15 patrol officers around, telling some to focus on hot spots while assigning routine calls to everyone else. "I base a lot of it on numbers," he says.

Twenty years after the New York Police Department pioneered the idea with a program called CompStat, computerized crime analysis is moving to a new level. Back then, the innovation was a map tracking past crimes, which higher-ups used to hold district commanders accountable. Now the push is for widespread adoption of analytics that predict crime in close to real time, identifying target areas to within 250,000 square feet. Bigger data sets, commercially available analytics and forecasting software, and faster computers are driving the improvement, say the Rand Corporation's John Hollywood and Walt Perry, authors of a 2013 report on the trend.

Critics like the Electronic Frontier Foundation, however, fear that such projects will promote racial profiling, and skeptics like Maria Haberfeld, a professor of criminal justice at John Jay College, think they are as likely to move crime a few blocks away as they are to prevent it.

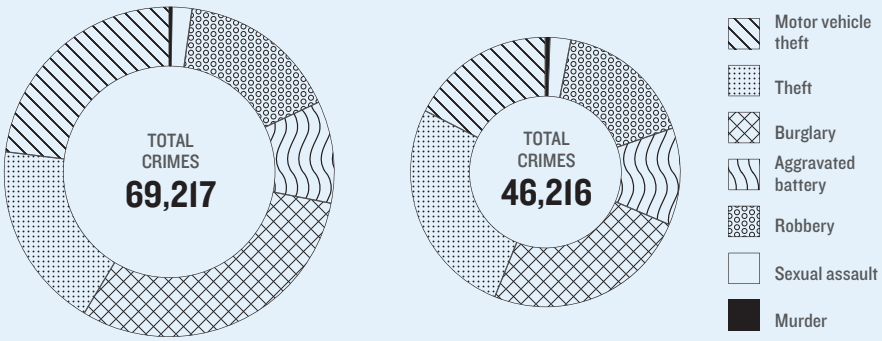
Some big departments, like the Los Angeles Police Department, simply base predictions on data about past crime locations and time and type of crime, says UCLA anthropologist Jeff Brantingham, who is also cofounder of PredPol, the company that helped design the LAPD's software. At the other extreme is Chicago, which has gone as far as using data to predict whether specific potential criminals may be involved in violence. Fort Lauderdale takes a middle path: it uses crime history but factors in details such as events that are expected to draw crowds, and even the likely impact of weather.

The analytics aren't good enough to say a specific store will be hit on Tuesday, but they can predict a 70 percent chance of burglaries in one area, or a 40 percent chance of muggings somewhere else.

The approach seems to work—but as with any experiment in a living city, it's hard to be certain why crime is down. In Fort Lauderdale, crimes like murder, robbery, larceny, and sexual assault fell 6 percent in the first eight months of 2014. Assistant police chief Michael Gregory says that in addition to the computer analytics, the department has implemented tactics such as distributing anti-theft kits in a burglary-prone neighborhood.

In Chicago, violent crime was down 13 percent year over year as of October, and the number of murders could be the lowest since 1965. Chicago's "hot people" strategy was based on a list of the 400 Chicagoans, all with arrest records and connections to known criminals, →

Chicago Crime Scene
Technology has helped lower crime



SOURCES: CHICAGO POLICE DEPARTMENT; QIUSHI JOURNAL

that a computer model identified as most at risk of becoming either a perpetrator or a victim of violence, though it can't predict which.

Since 2013, people on the list have been getting personal visits from local cops—usually the head of their precinct, according to Commander Jonathan Lewin, head of the department's public-safety information technology unit. They're handed a letter that explains the consequences of breaking the law and offers social services. The hot 400 are as much as 500 times more likely than average to be involved in a crime, Lewin says, and most of the data used to build the list has to do with the level of connectedness to criminals: "It does not—repeat, not—include gender or race." There have been some problems, including reports that minor offenders were listed. Soon the list will be weighted by probation history, outstanding warrants, and record of narcotics and weapon possession.

Los Angeles eschews modeling aimed at identifying specific criminals, and Brantingham warns that nothing in predictive policing generates enough probable cause for a search warrant or justifies a stop-and-frisk. In the end, even the best systems can't entirely replace human judgment."It takes a little time for people to get out of the mind-set that it's a cure-all," Brabble says.

Video and social networks like Twitter are increasingly sources of data for analysis, and in time, systems with more decision support built in may be deployed as well, putting more data into the hands of officers using mobile devices and in-car computers in the field. One thing that won't change: controversy over what kinds of data are relevant, and politically acceptable, to include in crime forecasting. *—Tim Mullaney*

Case Study

China's Future City

China has put political muscle and technology into Tianjin Eco-City.

● Strolling along sidewalks shaded by plane trees, one might take Tianjin Eco-City for just another of the many residential areas sprouting up all over China. But on closer inspection, this place is different. The roadside trash cans are covered with solar photovoltaic panels so they can light up at night; free electric buses connect different districts; the drainage wells for storm water are all embedded in the curbs.

There are less obvious features, too. The pavement is laid with pervious sand bricks for efficient drainage, and the water supply is designed to minimize leakage. Rainwater and wastewater are collected separately, and 18 submersible axial flow pumps capable of pumping 42.1 cubic meters of water per second divert the rainwater to artificial wetlands.

Here, on a piece of land about one-half the size of Manhattan, is one of China's first attempts at sustainable urban development. It aims to address two of China's most pressing challenges: the rapid population migration stressing the country's already-large cities, and its growing pollution and environmental problems. The national government has praised the project as a success, but only 20,000 people have moved in, a fraction of the 350,000 the city is designed to house by 2020.

The Eco-City project, a collaboration of China and Singapore, is located on the eastern border of Tianjin, a manufacturing city of nearly 15 million people. Total investment has not been disclosed, but project officials say that as of 2012, 40 billion yuan ($6.5 billion) had been invested in fixed assets. Tianjin is one of four cities directly governed by China's central government, and the Eco-City is located in its first "comprehensive reform and innovation area," a designation associated with favorable investment and trade policies.

If it succeeds, Tianjin Eco-City would become a model. The country has 171 cities with populations over one million, and its total urban population is projected to rise to about one billion by 2030. By that time, close to 70 percent of China's population will be living in urban areas. China's cities can be difficult places to live. Beijing's smog has become internationally famous. Water is an issue too. According to China's Ministry of Environmental Protection, 57 percent of the groundwater in 198 cities tested in 2012 was rated either "bad" or "extremely bad."

$6.5 billion
Investment in Eco-City infrastructure

The goals set for the Eco-City include zero net loss of natural wetlands, a recycling rate of at least 60 percent, and a minimum of 12 square meters of public green space per capita. Six years after

ground breaking, planners say they have achieved most of those goals, though Liu Xu, director of the ecological and environmental monitoring center at the Eco-City's administrative committee, acknowledges "temporary deviations" from the standards set for ambient air quality, which he attributes to the impact of the surrounding environment.

The Eco-City's small population is a worrisome sign, however, says Bao Cunkuan, a professor of environmental science and engineering at Fudan University. By building an eco-city from scratch, Bao says, "more often than not, we build a city that is disconnected from the reality and without the human element."

Other than the lunch rush of Eco-City managers, the only crowds on the quiet streets form when parents pick up the 2,300 students at the area's kindergartens and schools.

It was the schools, not the environmental programs, that convinced 38-year-old Fan Hongqin to move to the Eco-City a year ago. Her daughter is in second grade at a school with an emphasis on foreign languages. The city encourages enrollment by offering free school bus service, free meals, and monthly subsidies of 1,000 yuan ($163) for apartment-owning parents of kindergartners. "The environment here is more livable; that's true," said Fan, shortly after school pick-up one September afternoon. But the location is inconvenient. Even to buy clothes, Fan says, she must travel into other sections of Tianjin. The city center is an hour away.

The Eco-City is clearly a big environmental improvement from what sat on this land before: a one-square-mile wastewater reservoir. Containing mercury and DDT, it had lost all its ecological functions following years of heavy pollution by industry. Restoration cost one billion yuan ($163 million). "What used to be barren saline and alkaline wasteland has now been transformed into an emerging new green city," says Ho Tong Yen, CEO of the Sino-Singapore Tianjin Eco-City Investment and Development Company. "We are not just a lofty plan but an actual, emerging city," he adds. "We are for real."

—Yiting Sun

Q&A

Smart Cities Will Take Many Forms

Technology can make cities increasingly machine-like or more social and creative, says author Anthony Townsend. Both models can work.

● In cities across the world, mayors, urban planners, citizens, and, increasingly, tech companies are using powerful new devices and programs to create smart cities, where transportation systems, energy grids, and public services can be monitored and manipulated in real time. We should be careful about how we enable ubiquitous computing to change and control our cities, cautions Anthony Townsend, a senior research scientist at the Rudin Center for Transportation Policy and Management at New York University and author of *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. As a researcher, Townsend has studied how cities apply technology for the past 20 years. He spoke with journalist Nate Berg for the Business Report.

The world's urban population is expected to nearly double by 2050, to more than six billion people. What role can technology play in easing this transformation?

I think the most interesting role is in enabling the livelihood of a large number of those six billion people, particularly in the developing world. Smartphones are the technology that I think is the most important. Pretty much everybody on the planet will have a phone, and anybody who lives in a city will have a smartphone. We're going to have billions of still relatively poor people walking around with networked supercomputers in their pockets. There's been research that's shown that mobile-phone service has a pretty detectable impact on GDP in poor countries. Smartphone technology—all the services that can be delivered over it—I think will have an even more significant impact.

What does a city taken over by computers—or perhaps smartphones—look like?

A city that's taken over by computers designed by a big technology company is going to look like a machine. It's going to be highly automated, highly centralized, and very efficient. It may not be a lot of fun, it may not be terribly respectful of our desire for privacy, it may not be very resilient. On the other hand, we could design cities that have a very decentralized, very redundant kind of infrastructure where the services that we create using sensors and displays and all these digital technologies are trying to achieve objectives that are more in line with increasing social interaction, increasing sustainable behaviors, reinforcing the development of culture, creativity, and wellness. So there are very different possible outcomes. It's really up to the choices we make.

Cities are "basically taking the long-term vision they've already developed about what they want their city to be and trying to figure out how technology can be in service of that vision."
—Anthony Townsend

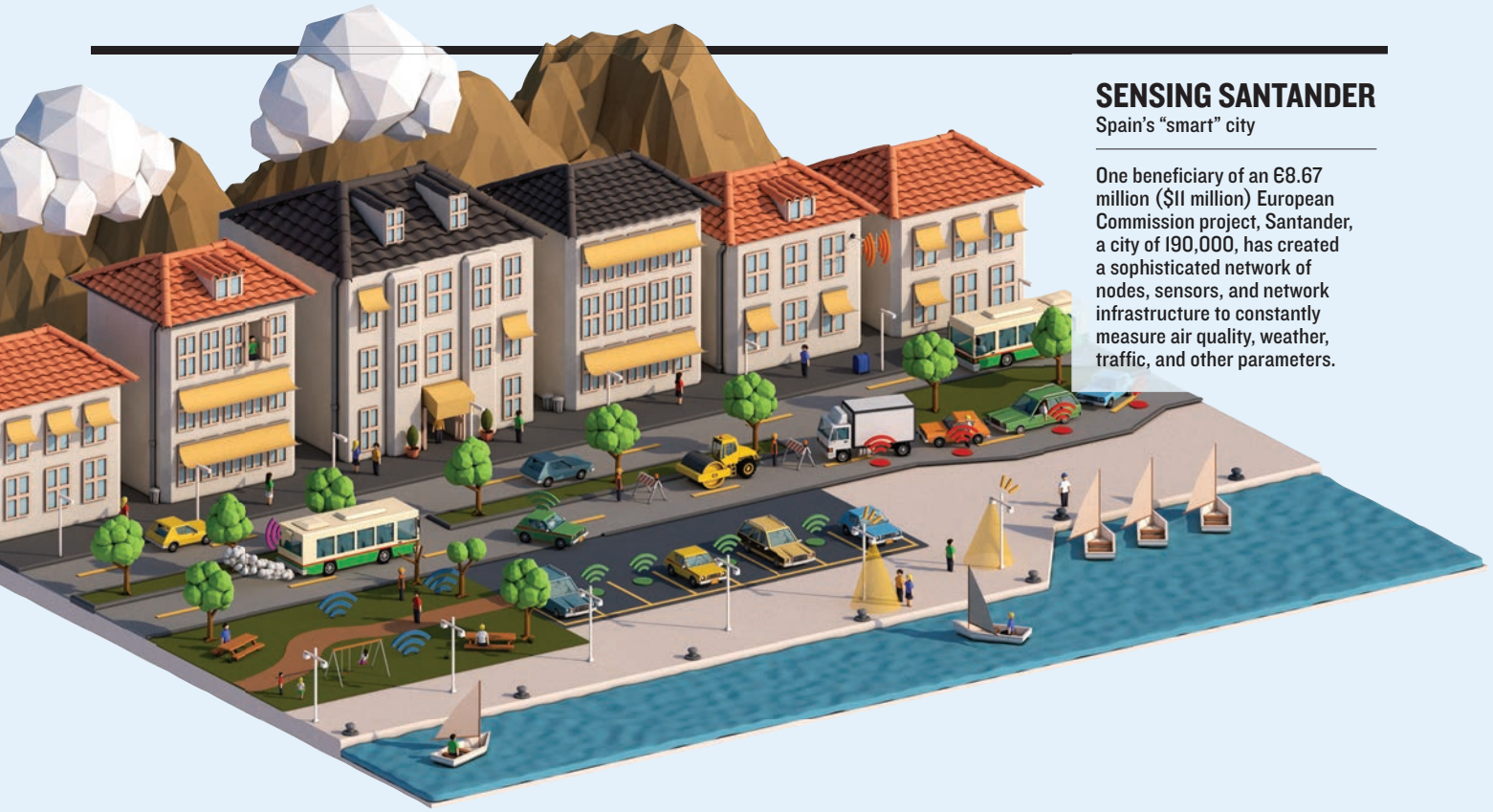
Smart cities are being pushed by big technology companies. Your book explores these efforts but also highlights some bottom-up approaches to making our cities smarter. Which offers a better way of managing the modern city?

A very promising development is we're seeing mayors and other civic leaders take on the challenge of figuring out what the vision of the smart city should be and how to draw on all of the differ- →

ent resources that can provide technical expertise and innovations that will allow it to happen. This is why I'm so interested now in how cities are making long-term technology plans, because they're basically taking the long-term vision they've already developed about what they want their city to be and trying to figure out how technology can be in service of that vision.

Are we expecting unrealistic things from the ways technology can affect our cities?
I think there are different kinds of utopias. The utopia of a perfectly controlled, perfectly efficient, safe smart city may work in a place like Singapore, and in fact they're well on their way to building that. But it probably wouldn't work in New York or São Paulo, where the expectations about what success looks like and what a healthy community is are totally different. Cities aren't uniform. The thing about digital technology is it's incredibly flexible and modular. So it's really exciting to see all of the different combinations of parts that people can throw together to create often highly localized services that let people experience the city in different ways.

So even if Singapore creates a great smart city, we shouldn't necessarily export those ideas wholesale to other cities.
That command-and-control model is very expensive. Singapore can do it because Singapore is a very wealthy country. But you're probably not going to see that in Nairobi or Johannesburg or Lagos. And I think that's where you're going to see a lot more reliance on the kinds of devices that consumers are able to provide themselves. We already see this in transportation planning, where great strides are being made in understanding travel patterns in some of the poorest cities on earth because we're able to see it in the mobile-phone data. Transportation is among the top barriers to managing a successful city in the developing world. It's the thing you have to get right if you're going to be able to do anything else, and we've just deployed [in mobile phones] the best transportation sensing network in the history of mankind, completely by accident.



SENSING SANTANDER

Spain's "smart" city

One beneficiary of an €8.67 million ($11 million) European Commission project, Santander, a city of 190,000, has created a sophisticated network of nodes, sensors, and network infrastructure to constantly measure air quality, weather, traffic, and other parameters.

PARKING
To reduce driver frustration and emissions from idling cars, 400 ferromagnetic sensors, buried in public parking lots, track open parking spots.

ENVIRONMENT
More than 2,000 sensors measure noise, light, temperature, and the carbon in the air, helping the city obey regulations on noise and air quality.

LIGHTING
Sensors embedded in lampposts in parks sense pedestrians and reduce lighting when nobody is around.

TRAFFIC
Sensors under the pavement at the city's entrances track traffic volume and location, and the speed of cars.

SOUND
Sensors are building a sound map to help the city comply with E.U. noise regulations.

IRRIGATION
Sensors at four parks record thousands of observations about the humidity, temperature, and moisture in the soil each day, enabling the city to conserve water.

MICHIEL VAN DEN BERG

Emerging Technologies

Car-Based Technology That Could Invigorate Cities

U.S. carmakers are leading the development of vehicle communications technology, and it could be a boon to city planners.

● As declines go, Detroit's has been spectacular. So it's a little strange to discover—just a short drive north of downtown, past countless deserted office blocks and homes—something that could help make cities safer, more energy-efficient, and generally more pleasant to live in. In Warren, Michigan, General Motors is testing technology that lets cars transmit and receive useful information wirelessly across several hundred meters.

Well before fully automated vehicles like Google's self-driving car hit the roads, so-called vehicle-to-vehicle communications should improve road safety by warning drivers of an impending collision or alerting them to treacherous road conditions ahead. The technology should also complement greater vehicle automation, providing a clearer picture of surroundings than onboard sensors alone and letting automated vehicles coördinate their actions. Eventually, connected vehicles should also benefit cities, acting as mobile sensors within vital transportation arteries and helping prevent accidents, control congestion, and reduce energy use.

Over time, the information gathered from connected cars could even reveal urban patterns to guide policy makers and planners. City planners armed with huge amounts of traffic-flow data could more easily identify problem intersections, for instance, or pinpoint the ideal spot for a new bus stop.

Before cities can realize the benefits of connected vehicles, however, the technology required to network cars wirelessly needs to be worked out. And at its R&D facility in Warren, GM is testing what's likely to be the first generation of car-to-car communications.

Hariharan Krishnan, a GM technical fellow, took me for a spin around campus in a luxurious but otherwise normal-looking Cadillac. As we approached an intersection, one of Krishnan's colleagues accelerated toward us from the left in another car. The second vehicle was obscured from view by an inconveniently located bush, but a few seconds before impact, red lights flashed on the Cadillac's dashboard, the front seats buzzed a warning, and Krishnan hit the brakes. While some high-end cars are already equipped with automated braking systems that rely on cameras, radar, or other sensors, GM's wireless system has a longer range, and it can see hazards around corners or behind obstructions. "You can see that I was completely blinded," Krishnan said as the other car flew by. "The technology is uniquely positioned to help in these blindside collisions."

Both cars were equipped with wireless transmitters and receivers that relay position, speed, direction of travel, and other information to nearby vehicles 10 times per second. The equipment uses a frequency allocated in part for car-to-car communications by the Federal Communications Commission, and all data is encrypted. A computer stashed in the trunk of our vehicle recognized an impending collision and automatically sounded the alarm. The setup could help in other situations—preventing rear-endings, for example, by warning that a car ahead has hit the brakes. It might also warn of ice on the road ahead, based on other vehicles' braking information.

Earlier this year the University of Michigan's Transportation Research Institute concluded a two-year, government-funded project called the Safety Pilot Study that collected data from nearly 3,000 vehicles fitted with wireless communications equipment. The results suggested that wireless communications could prevent more than 500,000 accidents and 1,000 deaths each year on U.S. roads, and the National Highway Traffic Safety Administration announced in August that it would begin drawing up rules to mandate the technology in new vehicles.

Some car companies are a step ahead. In September, GM announced that in 2017 it will begin selling the first car in the U.S. equipped with car-to-car communication as a safety feature.

The opportunities for connecting these vehicles to city infrastructure can be found a 45-minute drive west of Detroit, in the city of Ann Arbor, where researchers from the University of Michigan are experimenting with transmitters added to roadsides and built into infrastructure such as traffic lights. At one point during a demo, the display warned the driver that he was approaching a sharp curve too quickly; at another it showed when the traffic light ahead was about to change.

The real benefits will come if cities use this data to guide decisions about traffic management and long-term planning.

The real benefits of these systems will come if cities use this data to guide decisions about traffic management and long-term planning. And for many, connecting vehicles and infrastructure will create a vastly more intelligent traffic system.

But car-to-car communication could prove tricky for cities. The addition of such technology to city infrastructure is unlikely to be mandated, leaving it up to local governments to decide whether they can afford the cost.

Alexei Pozdnoukhov, director of the Smart Cities Research Center at the University of California, Berkeley, says that in the end, it might be more cost-effective for cities to try to use smartphones to track drivers' movements. *—Will Knight*

Case Study

Booming Lagos, Smart City

An African mega-city bets on technology and its native entrepreneurs to meet the many challenges of its population boom.

● For Lagos, Nigeria, Africa's biggest city, any push to become a smart city will have to adapt to constant—and often unplanned—growth.

Its challenges are epic. The United Nations predicts that Lagos's population—which the U.N. estimates at 12.6 million today, though other estimates are as high as 22 million—will almost double between now and 2030, greatly adding to demands on already strained services.

Can this city, where the poorest live in fetid floating slums, absorb another 12 million souls? "Keeping up with the state's growing appetite for services and resources is a Herculean and continuous process," acknowledges Lagos state governor Babatunde Raji Fashola. "The need to deploy innovative approaches that address civic challenges in Lagos state has never been greater, and technology is the key to the future."

As Lagos lays out its vision for becoming a smarter city, international IT companies are vying for its business, betting that technology and data will be the keys to its evolution. Mobile phones, extraordinarily popular on the African continent, are expected to lead the way.

Uyi Stewart, chief scientist of IBM's Africa Research Lab, calls the city "one of Africa's economic and demographic powerhouses" but argues that it won't successfully manage its growth without IT, including mobile and cloud technology, social media, and business analytics. IBM launched a new innovation center in Lagos earlier this year, part of a broader investment in Africa.

Last year a six-person IBM team spent a month working with government agencies to analyze the city's transportation systems. Lagos traffic jams are epic. The drive to the airport from Victoria Island, home to the city's embassies, top hotels, and biggest businesses, takes only 45 minutes at night, but someone with an 11 A.M. flight will need to leave before 6 A.M. when the traffic locks. One area of IBM's focus was the expansion of transportation services using the city's myriad waterways, which already carry more than 170,000 commuters a day but could carry many more if transport systems were optimized on the basis of cloud computing, analytics, and mobile data. Analytics technology applied to data stored in the cloud could predict water traffic, streamlining traffic flow. That would then feed into cell-phone updates for commuters about the best times to travel and how long their trip is likely to take.

The project was part of IBM's Smarter Cities Challenge initiative, a three-year, 100-city, $50 million competitive grant. One private-sector initiative is IBM's work with Virtual Streets, a Nigerian startup, using cognitive computing systems to provide location-based services to people in Nigerian cities. Using data from geographic information systems, traffic cameras, and phones from subscribers, Virtual Streets gives subscribers real-time traffic data paid for by location-based ads for local businesses.

"There is already ample data available in Lagos," says IBM's Stewart. "Cell phones, social media, traffic cameras, global positioning systems, banks, and retail stores are all producing terabytes of big data loaded with potential insight about how the city works and how its citizens move around within it." The challenge is figuring out how to actually use all that information.

The Eko Atlantic project is key to the city's regeneration. It is a planned district being constructed on land reclaimed from the Atlantic Ocean. Upon completion, the new island will house 250,000 residents and a daily flow of 100,000 commuters. Sand reclamation and the building of a seawall, sometimes referred to as the Great Wall of Lagos, are set to be completed by 2018. All infrastructure work is to be done by 2020, according to David Frame, managing director of South Energyx Nigeria Limited, the developers and city planners of Eko Atlantic.

Lagos has a strong technology startup scene that should help the city as it evolves. Its CcHUB, where technologists, social entrepreneurs, and investors gather to create solutions to Nigeria's social problems, compares well with similar spaces in other parts of Africa and in Europe.

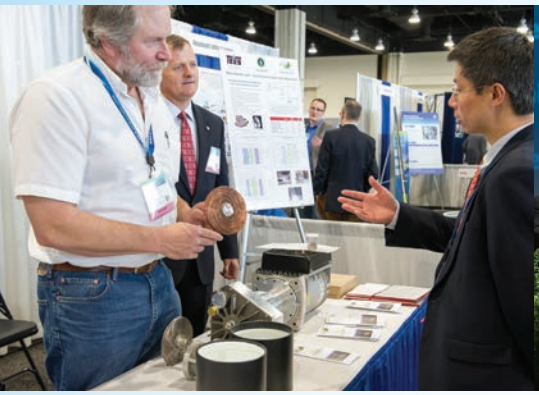
Still, basic challenges remain. Electricity is not delivered consistently, and for every paying customer, there are countless others who illegally piggyback on utilities. Vandalism and theft of critical network infrastructure are endemic. Moreover, while mobile-phone penetration in Lagos is high, smartphones have been slow to take hold. Hitendra Naik, director of innovation for Intel Sub-Saharan and South Africa, says one promising development is local initiatives that have helped companies lay down new fiber-optic lines in return for connecting or subsidizing rates to local schools. Another popular initiative uses data capture and analysis to let people submit applications for a vehicle license electronically, then walk into a bank to print it off—a quicker and simpler alternative to chaotic queues at government offices with a waiting time of weeks or even months.

—Monty Munford

Since Hurricane Sandy, computer models have taken on the tricky task of predicting storms.

▶ See how they work, plus dispatches from Barcelona, Amsterdam, and Jakarta and the rest of our report on cities, at **technologyreview.com/business.**

VIKTOR HACHMANG



arpa·e energy innovation summit

February 9–11, 2015 | Washington, D.C.

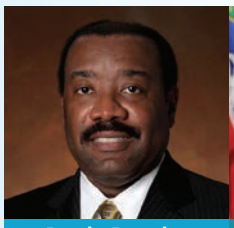
ABOUT ARPA-E

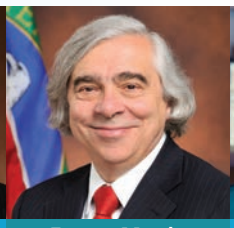
The U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) invests in disruptive ideas to create America's future energy technologies. ARPA-E focuses exclusively on early-stage technologies that could fundamentally change the way we generate, use, and store energy.

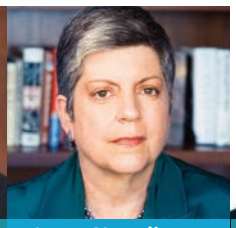
ABOUT THE TECHNOLOGY SHOWCASE

The Technology Showcase at the 2015 ARPA-E Energy Innovation Summit presents America's next generation of transformational energy technologies. The Summit draws hundreds of prominent investors, government agency officials, and corporate executives who are actively looking for strategic partnerships, investment opportunities, and licensing/IP deals. Exhibitors include ARPA-E awardees and a highly selective group of other companies and research organizations.

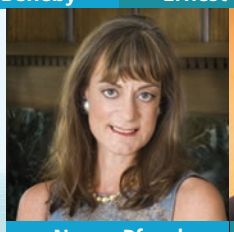
FEATURED KEYNOTE SPEAKERS (as of 12/7/14)

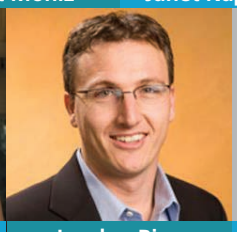

Doyle Beneby

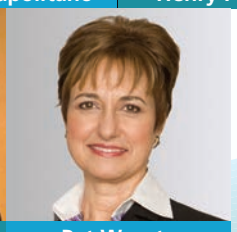

Ernest Moniz


Janet Napolitano


Henry Paulson


Nancy Pfund


Lyndon Rive


Pat Woertz

SPECIAL OPPORTUNITIES AT THE SUMMIT

FOR TECHNOLOGISTS:

- Discover new grant opportunities at the Government Agency Networking Program
- Get matched with investors and executives through the Corporate Acceleration Program (CAP)*
- Apply to the Future Energy Pitch Session and pitch your idea to high-profile investors
- Attend practical seminars, hands-on workshops, and focused networking sessions
- Meet with companies actively hiring for R&D positions

FOR INVESTORS:

- Investor/Awardee Networking Breakfast
- Corporate Acceleration Program (CAP)*
- Student/Recruitment Programs
- Engaging agenda and much more

**The Corporate Acceleration Program is a matchmaking program that pairs investors and executives with pre-screened researchers who are working on promising, early-stage energy technologies. Corporations have a unique opportunity to find potential investments, R&D partnerships, and new IP/licensing deals.*

FOR PARTNERSHIP OPPORTUNITIES

Laurie Powell
eventPower
Phone: (703) 740-1940
LPowell@eventPower.com

FOR SUMMIT LOGISTICS

Sommer Jackson
eventPower
Phone: (703) 740-1954
SJackson@eventPower.com

www.ARPAE-Summit.com

Illustration by Brecht Vandenbroucke

Reviews

What Are MOOCs Good For?

Online courses may not be changing colleges as their boosters claimed they would, but they can prove valuable in surprising ways.

By Justin Pope

A few years ago, the most enthusiastic advocates of MOOCs believed that these "massive open online courses" stood poised to overturn the century-old model of higher education. Their interactive technology promised to deliver top-tier teaching from institutions like Harvard, Stanford, and MIT, not just to a few hundred students in a lecture hall on ivy-draped campuses, but free via the Internet to thousands or even millions around the world. At long last, there appeared to be a solution to the problem of "scaling up" higher education: if it were delivered more efficiently, the relentless cost increases might finally be rolled back. Some wondered whether MOOCs would merely transform the existing system or blow it up entirely. Computer scientist Sebastian Thrun, cofounder of the MOOC provider Udacity, predicted that in 50 years, 10 institutions would be responsible for delivering higher education.

Then came the backlash. A high-profile experiment to use MOOCs at San Jose State University foundered. Faculty there and at other institutions rushing to incorporate MOOCs began pushing back, rejecting the notion that online courses could replace the nuanced work of professors in classrooms. The tiny completion rates for most MOOCs drew increasing attention. Thrun himself became disillusioned, and he lowered Udacity's ambitions from educating the masses to providing corporate training.

But all the while, a great age of experimentation has been developing. Although some on-campus trials have gone nowhere, others have shown modest success (including a later iteration at San Jose State). In 2013, Georgia Tech announced a first-of-its-kind all-MOOC master's program in computer science that, at $6,600, would cost just a fraction as much as its on-campus counterpart. About 1,400 students have enrolled. It's not clear how well such programs can be replicated in other fields, or whether the job market will reward graduates with this particular Georgia Tech degree. But the program offers evidence that MOOCs can expand access and reduce costs in some corners of higher education.

Meanwhile, options for online courses continue to multiply, especially for curious people who aren't necessarily seeking a credential. For-profit Coursera and edX, the nonprofit consortium led by Harvard and MIT, are up to nearly 13 million users and more than 1,200 courses between them. Khan Academy, which began as a series of YouTube videos, is making online instruction a more widely used tool in classrooms around the world.

All this activity is beginning to generate interesting data about what MOOCs actually do. In September, MIT physicist David Pritchard and other researchers published a study of Mechanics ReView, an online course he teaches that is based on an on-campus course of the same name. The authors found that the MOOC was generally effective at communicating difficult material—Newtonian mechanics—even to students who weren't MIT caliber. In fact, the students who started the online course knowing the least about physics showed the same relative improvement on tests as much stronger students. "They may have started with an F and finished with an F," Pritchard says, "but they rose with the whole class."

"Learning in an Introductory Physics MOOC: All Cohorts Learn Equally, Including an On-Campus Class"
The International Review of Research in Open and Distance Learning
September 2014

Online master's program in computer science
Georgia Tech, Udacity, and AT&T

Pritchard still questions the effects MOOCs will have; for one thing, he doesn't see how they can have a sustainable business model on their own. But that doesn't mean MOOCs are merely another overhyped technology. Ideas about what they offer, and whom they might help, are evolving as rapidly as the MOOCs themselves.

Valuable snippets

One thing worth reconsidering is MOOCs' famously high dropout rates. A widely cited figure is that 90 percent of students don't finish their courses; a study at Penn determined that the number was 96 percent.

Pritchard, for one, calls the focus on initial registrants misguided. Most who sign up for a class aren't serious students; they're window shoppers who face no cost barrier to trying a lecture or two. Half of the people in the Penn study dropped out before the first class. Of 17,000 who signed up for Pritchard's MOOC, only about 10 percent made it as far as the second assignment. But more than half of those earned a certificate of completion.

"We're nearing the point where it's a superior educational experience, as far as the lectures are concerned, to engage with them online," says a Harvard professor. If that's true, traditional universities will have to show that most of the other things they offer on campus can't be replaced by technology.

For some people, especially adults in search of continuing education, even dropping out of a MOOC may well be a kind of victory—over an old model of credit-hours and semester-long courses that makes no sense for them. If they want to see whether they'd be interested in a topic, or just want snippets of material, why should they pay for, and sit through, an entire 12-week syllabus?

For all the hype, MOOCs are really just content—the latest iteration of the textbook. And just like a book on a library shelf, they can be useful to a curious passerby thumbing through a few pages—or they can be the centerpiece to a well-taught course. On their own, MOOCs are hardly more likely than textbooks to re-create a quality college education in all its dimensions.

Justifying tuition

When Harvard and MIT announced the creation of edX, they said a major goal was to jump-start innovative teaching to their own students. That got little attention, at least beyond Cambridge, but there are signs it is happening. Many of the technologies central to MOOCs, built around interactivity and assessment, can be useful tools for students on campus, says MIT's director of digital learning, Sanjay Sarma. MIT students can't get credit for taking even MIT-produced MOOCs, but they still use MOOC tools in their courses. Two-thirds have taken a traditional course that uses the edX software platform.

Down Massachusetts Avenue, Harvard computer scientist David Malan says his campus has also seen "a marked uptick" in conversations about reinventing teaching. Malan's Introduction to Computer Science course captures many of these currents. The on-campus version is Harvard's most popular, with around 800 students. The MOOC version has about 350,000 registrants from around the world, ranging from preteens to 80-year-olds. Both versions use sophisticated, overlapping learning resources, from lecture videos to assessments. Their academic standards are the same.

Malan began videotaping lectures in 1999, but he says the tools of the MOOC bring a new dimension to his teaching. For example, lectures that typically take an entire class period can be broken up online into shorter, more focused units, allowing students to spend as much time on each segment as they need.

The paying Harvard students decide for themselves whether to attend the lectures or just catch them online. "I would like to think there's a nontrivial psychological upside to the shared experience," he says, but it's up to them. Instead of necessarily having all 800 students attend each lecture, "I would rather have 400 students who want to be there," he adds. Besides, "we're nearing the point where it's a superior educational experience, as far as the lectures are concerned, to engage with them online."

If that's true, it's a terrifying but useful prod for traditional universities. At MIT, the edX experiment has been "a huge stimulus," says Pritchard. Across higher education, "it's making everybody sit up and answer the following question: 'How can I justify charging students $45,000 a year to attend large lectures when they can find better exemplars on the Internet?'"

In Malan's course at Harvard (where tuition, fees, room, and board actually run $58,607 this year), part of the answer is that even if the academic standard is identical, the full experience is not. The Harvard students get course sections and recitations with just a few students, a 90-minute weekly recap of the material, and office hours four nights a week (the class essentially takes over a dining hall). The on-campus course is almost cinematic in its production scale, with a staff of 100. To assist orders of magnitude more students in the MOOC, five staff members wade into discussion forums, along with student and alumni volunteers.

And of course, students not just at Harvard but at hundreds of other universities get much more than that. They get a credential that is necessary for many types of employment, plus access to alumni networks and mentorship.

That's why MOOCs shouldn't necessarily threaten colleges: if established institutions make judicious use of learning technology where it demonstrably helps students, they gain credibility to insist that most of what else they offer on campus is a qualitatively different experience—one that technology can't replace.

Teaching teachers

Education researchers are still just beginning to mine all the data that MOOCs generate about how students respond to the material. Researchers like Pritchard can track every step of every student through a MOOC; he says that for him to study his traditional students that way, "they'd have to carry a head-cam 24-7." Eventually, such data should yield insights about the best ways to present, sequence, and assess particular subjects. Kevin Carey, who has researched MOOCs as director of education policy at the New America Foundation, points out that today's MOOCs haven't even begun to make serious use of artificial intelligence to personalize courses according to each student's strengths and weaknesses (a surprise considering that pioneers like Thrun and Coursera's Daphne Koller came from AI backgrounds).

Yet while MOOCs' huge enrollments are fantastic for running educational experiments, it makes them hard to teach. Pritchard's MOOC represents a much wider range of abilities than his on-campus class at MIT. "It's like we're trying to teach from second grade up to seventh," he says. His new project is an Advanced Placement physics course for high school students. By narrowing the target audience—high school students who believe they're ready to take AP physics are likely to start within a fairly tight band of knowledge—he thinks he can teach more effectively than would be possible in a more diverse MOOC.

Indeed, for all the focus on the role of MOOCs in higher education, they might have a significant role to play in high schools and below. Teachers are already a big audience (a study of 11 MOOCs offered by MIT last spring found that nearly 28 percent of enrollees were former or active teachers). This is particularly promising because teachers pass what they learn on to their own students: when they make use of edX and other resources in their classrooms, they multiply the effect. As Coursera moves explicitly into teacher training, its classes could have as much impact by reaching a few hundred teachers as they would with thousands of other students.

For all the focus on the role of MOOCs in higher education, they might have a significant role to play in high schools and below. Nearly 28 percent of enrollees in one group of online classes were current or former teachers.

MOOCs alone can't meet the oversized expectations of early boosters like Thrun—who themselves echoed would-be reformers over the decades who looked to radio, television, and the mail to democratize learning (see "The Crisis in Higher Education," November/December 2012). For better or worse, traditional methods of higher education showed remarkable persistence as those models emerged. Yes, this time might be different. But if MOOCs do prove revolutionary, it will be because educational institutions have finally figured out how to use them.

Justin Pope, a former higher-education reporter for the Associated Press, is chief of staff at Longwood University in Virginia.

Auras: There's an App for That

A variety of new digital filters will make a photograph look vintage. The inauthenticity of the effect is irrelevant: it's enough to evoke an audience's sense of the past.

By A. D. Coleman

In 1977, at the International Center of Photography in New York, the late American photographer William DeLappa exhibited a series of black-and-white images entitled "The Portraits of Violet and Al." Revolving around the title characters, it appeared to be a collection of several dozen photographs made by different people from the late 1940s through the early '60s. Most were snapshots, though one looked like an ID picture made for some official purpose.

The images described a considerable span of time. Violet and Al met and married during his post–World War II military service; they made friends, visited relatives, celebrated Christmas, and aged, remaining childless. Hairstyles, fashions, modes of interior decorating, automobile design, and architecture changed. DeLappa's gelatin-silver prints seemed to add up to a typical, even archetypal, white middle-class American family album. No one would have thought to question the authenticity of those pictures because their fidelity to a set of conventional photographic cues certified them.

Yet they were all fakes—made over the course of a year in the early '70s, at interior and exterior locations selected by DeLappa, using props and costumes he provided and enacted by friends and relatives he cast in various roles. The images were printed and artificially aged by the photographer, who had worked for some years in the studio of a photo restorer and learned all the tricks of that trade. The series was a virtuoso display of subversively self-effacing craft; DeLappa's mastery of materials and processes was evident in his ability to duplicate convincingly a remarkable range of vernacular imagery.

At the time, it struck most people as merely eccentric; besides me, few critics took notice of it. Today it seems unintentionally prophetic. Yet at the same time it has lost all its potency as provocation—because with images created and transmitted digitally, everyone can easily do what DeLappa achieved so laboriously in analog form.

"The Portraits of Violet and Al," by William DeLappa

Instagram

Hipstamatic

Vintage Scene

Retro Camera Plus

AgingBooth

Lomography

Distressed images

For some years, we've had access to applications that can repair digital scans of old analog images showing signs of damage, whether from dirt and creases or overall fading. With these tools you can make your old photos look new.

At the same time, if you spend time online looking at selfies, or view cell-phone photos posted on sites like Flickr, Tumblr, or Pinterest, or subscribe to many Twitter feeds, or visit the blogs of photographers both professional and amateur, you'll have noticed that a great many new digital images look old.

When you make digital images yourself, with your cell phone or tablet or digicam, a wide and relentlessly multiplying variety of existing websites and downloadable apps enable you to artificially age those pictures—to purposefully "distress" them, as an antiques dealer would say. These tools represent a noteworthy shift in our cultural relationship to the credibility of the photographic image.

In his 1936 essay "The Work of Art in the Age of Its Mechanical Reproducibility," Walter Benjamin famously proposed, "That which withers in the age of mechanical reproduction is the aura of the work of art." For Benjamin, that "aura" combined all aspects of an artwork's physical presence, ranging from the singular, unduplicable characteristics of its original crafting through the nicks and patinas that evinced its passage through time and its life in the material world. Production of machine-made multiples—of artworks, Benjamin's main subject, but implicitly of everything else, from furniture to kitchen utensils—eliminated the artisanal uniqueness of handmade artifacts, he argued. Meanwhile, the interchangeability of all instances of the machine-made multiple drained the possibility of resonance from any single one.

If Benjamin had it right, then your local antique store wouldn't charge you hundreds of dollars for a usable but less

A variety of Instagram's filters (opposite) can be added to photos and adjusted to replicate the look of vintage prints like those made by the Polaroid SX-70, Kodachrome, or a photo booth.

than perfect version of your grandparents' post–World War II formica kitchen table and naugahyde chairs. A mint-condition Mickey Mouse lunchbox from 1954 wouldn't go for anything on eBay. And, hauling out the family album when you visit, your mother wouldn't unfold ever so carefully the yellowed newspaper clipping celebrating your victory in the spelling bee, or run her fingers lovingly across the faded photo of her long-deceased childhood dog.

Walter Benjamin was wrong. Aura does not adhere to particular types of objects created in specific ways. Rather, humans attribute aura to anything that has emotional resonance: a patiently hand-carved medieval altarpiece, to be sure, but also the desiccated wonton I once saw at the Smithsonian in an exhibition of archaeological discoveries from mainland China, a weathered copper ashtray from the 1933 Chicago World's Fair, or a World Series home-run baseball caught in the grandstand of Kansas City's Kauffman Stadium this past fall.

In the electronic age—the golden era of 20th-century radio, film, and television—we received convincing evidence that synthetic aura would suffice to evoke an audience's sense of connection to the past. Tint a contemporary film scene sepia, and the viewer time-trips back to the decades just before or after the end of the 19th century. Add a bit of artificial static and a megaphone's harshness to a recorded voice-over, and you're listening to a Depression-period news broadcast. Induce the flicker, scrolling, and distortion of an old black-and-white Motorola, and you've got a TV show that could have run right after *The Honeymooners*.

As communication technologies obsolesce, they become auratic—capable of triggering our sense of the passage of time as represented by those now outmoded tools and, even more important, conveying the reliquary aspect of the encoding media that delivered the content of those times. You may find the actual devices deployed as décor in period-themed restaurants, but few people (aside from dedicated collectors) wax nostalgic over the last century's film and slide projectors, still cameras, radios, TV sets, and hi-fi rigs—compared with the multitudes who recall fondly the experience of sitting in the classic movie theater, or their living rooms or bedrooms or basement rec rooms, watching or listening to whatever content they cherished as filtered through those delivery systems.

A facsimile of aura, it turned out, could function as a flavoring. Given the ever more sophisticated toolkit of simulation, it now takes the expertise of a connoisseur to tell the difference between authentic and artificial aura.

Almost immediately, Hollywood (and Madison Avenue) learned to replicate those effects convincingly, giving us the sizzle of aura, as it were, while dispensing entirely with the steak of authenticity. A facsimile of aura, it turned out, could function as a flavoring. Given the ever more sophisticated toolkit of simulation, it now takes the expertise of a connoisseur to tell the difference between authentic and artificial aura.

Most people don't care. The digital revolution has made the addition of synthetic aura into little more than an option on a menu, like the "Ken Burns effect" in iMovie. Take, for example, the sound of surface noise on a shellac or vinyl analog recording. I no longer play the 45s, 78s, and 33⅓ rpm LPs I own, relying instead on (preferably lossless) digital files imported into iTunes. But I recall, not entirely without fondness, the aural experience of the occasional pop or hiss on the records in my library. And I listen regularly to a digital playlist I've downloaded of obscure jazz records from the 1930s and '40s, ripped by some devotee from 78s without much subsequent cleaning up. Part of the ambience, and the sensory pleasure, comes from those extraneous, certainly unintended snaps and crackles.

I also sometimes listen to the Crash Test Dummies' song "God Shuffled His Feet," an entirely digital recording that includes the surface noise of an analog record as one of its sonic elements. They signify in differently nuanced ways, but they trigger the same physical memory of listening to recorded sound up through my early 50s, and if you isolated the surface noises I couldn't tell one aural experience from the other. (There are apps for this, too, such as Vinyl—the Real Record Player and VinylLove.)

For some time to come there will still be collectors of old shellac and vinyl, and audiophiles who succumb to the lure of those formats will continue to subsidize the production of new limited-edition recordings on vinyl even if the same content is distributed digitally. Some musicians still prefer to record on analog equipment. Similarly, there's a healthy market for photographic prints made with the standard gelatin-silver and color "wet" or "chemical" methods, and even a thriving revival of the earlier alternative processes: platinum, cyanotype, tintype, ambrotype, daguerreotype, each with its own distinctive look and feel. Not to mention Lomography, whose devotees make negatives with variants of a small, cheap Russian 35-millimeter camera. The photograph, created by a simple machine and (at least nominally) infinitely reproducible, exemplified for Benjamin "the contemporary decay of the aura." The booming market in "vernacular photography," with collections of snapshots entering museums for

This portrait of Violet from "The Portraits of Violet and Al" is the first in a portfolio of 28 photos by William DeLappa.

The use of apps to alter digital images represents a yearning for the visual look of earlier, analog forms of photography.

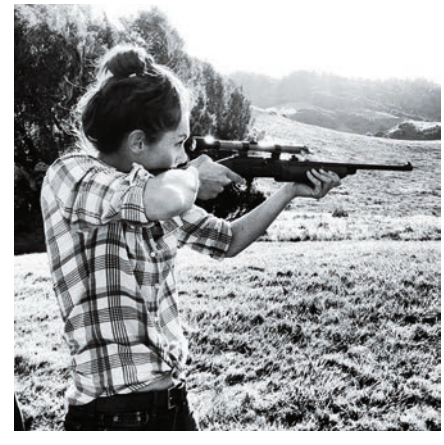
exhibition and preservation, surely gainsays that thesis. So does the flood of apps for the auratization of digital images. You can make your selfie look like a Polaroid SX-70 print, a bright, saturated 1950s Kodachrome image, a 1940s photo-booth portrait, a worn snapshot that someone carried in her wallet for decades. Indeed, you can capture any of dozens if not hundreds of ways that analog photographs, especially those made by amateurs, used to look in their heyday.

We can perhaps find in this the tendency toward what Marshall McLuhan called our rearview-mirror relationship to new media: the first thing we tend to do with them is to mimic what they replace. It's logical, then, that when introduced to digital imaging, we'd use it to replicate the look of analog photos.

But the vast majority of people who make digital images steadily, alter them in various ways, publish them online, and exchange them with others via social media don't strike me as mired in the past or needing the reassurance of some skeuomorphic link to their analog roots in order to feel at ease with the digital present. Most of them have tenuous analog roots at best. They come from an overwhelmingly younger demographic, of which the retrohipster and steampunk cohorts constitute only subsections. An increasing number of them have grown up with digital imaging





JESSIE WENDER (@JMWENDER)

as the primary form of picture-making in their lives. Many have never held a film camera or exposed a negative, much less developed negatives and made prints. They don't faux-SX-70 their latest digital image because it reminds them of the SX-70s they, or even their parents, once used; they do it because it lends that image a certain atmosphere. And they'll do the next one as a video, and turn it into an animated gif, a purely digital form.

Synthetic age

This usage of apps to alter digital images doesn't represent a haptic nostalgia for the tactile encounter with the photograph as an object. If it did, the Impossible Project, which manufactures present-day equivalents of various Polaroid films, including the film packs for SX-70 cameras, would be more popular. Instead, it represents a yearning for the visual look of those earlier, analog forms of the medium, which has become a signifier in itself.

These apps and sites, in effect, enhance digital images with an ersatz version of Benjamin's aura, so that anyone can layer any image with the digital simulation of its passage through time. Aura thus becomes a synthetic additive. Free or inexpensive apps such as Instagram, Hipstamatic, Vintage Scene, Retro Camera Plus, Reflex, Pic Grunger, ShakeItPhoto, and Pinhole HD (not to mention the comparable options in more sophisticated, high-end image management apps like Photoshop) let you indulge your wildest anachronistic impulses.

In fact, by using any of these in combination with the app AgingBooth, you can generate images that go both backward and forward in time. AgingBooth functions something like the kiosk devised by photographer Nancy Burson, who starting in 1976, in collaboration with several programmers from MIT, developed the first software algorithms making it possible to approximate how individuals would look as they grew older.

In 1990, Burson and crew exhibited an interactive version of the Age Machine






they had been developing throughout the 1980s; you sat down in a kiosk facing a monochrome monitor, hit a button, and *voila*!—the program added 25 years to your current appearance, in what Burson called a "prediction." You couldn't save that file, or send it anywhere, or even print it out. But I had a chance to try it at the Arles Photo Festival in 2000 (by which point the machine had become a vintage object in itself), and the experience, even if momentary, proved powerful.

Analog photography as we knew it allowed skilled practitioners to blend fact and fiction. Digital imaging gives those powers to the amateur picture-maker.

AgingBooth lets you make such images at any increment you select, not just 25 years; you can save those files and then do as you will with them. This means that you can make a portrait of yourself as you may have evolved by 2050—and then, using the above-mentioned Vintage Scene (which can make your photos look as if they were taken in different eras, going all the way back to the birth of photography), you can see how you'd have appeared as an octogenarian in 1850. Analog photography as we knew it in its first 150 years allowed skilled practitioners to blend fact and fiction. Digital imaging gives those powers to the most amateur picture-maker. As a result, photography's service as a vehicle for fantasy now stands alongside its function as a recording system and may supersede it. We have just begun to adjust our cultural assumptions about the photograph to keep up.

A. D. Coleman is an internationally known critic of photography and photo-based art.

Google Glass Is Dead; Long Live Smart Glasses

Even though hardly anyone wants today's head-worn computers, the technology is sure to march on.

By Rachel Metz

Two and a half years after Sergey Brin unveiled Google Glass with a group of skydivers jumping from a zeppelin above San Francisco, the computer you wear on your face is falling to its death. It's still not a finished consumer product. It's not even close to being something people yearn

YANN KEBBI

for, at least not beyond the Glass Explorers who each paid $1,500 for early access.

Although Google says it's still committed to Glass, several companies, including Twitter, have stopped working on apps for it. Babak Parviz, the creator of Glass, left Google in July for a job as a vice president at Amazon, where he's looking into new areas of technology. Even some of the early adopters are getting weary of the device. "I found that it was not very useful for very much, and it tended to disturb people around me that I have this thing," says James Katz, the director of emerging media studies at Boston University's College of Communication.

Intriguing possibilities remain. A device that could sense what you were doing at a given moment and serve up relevant information into your field of view could be incredibly useful as a memory aid and productivity enhancer.

A lot of this is Google's fault. Rather than spending years developing Glass in secret, Google trotted it out as an early "beta" product that was somewhat functional but finicky and literally in your face. It hoped that software developers would come up with killer applications and that the people wearing it would act as evangelists. Presumably, the strategy has led to some priceless insights for the next version—Google's online Glass forum brims with questions and feature requests from early users. But as Katz noted, it caused a social backlash. The "explorers" have become widely known as "glassholes." Why? The reasons are telling, and they help us understand where the technology could go next.

Glass didn't fail only because it looks weird. Another big misstep was the aspect that Katz mentioned first. Glass annoyed other people largely because of its lack of utility: no one could understand why you'd want to have that thing on your face, in the way of normal social interaction. Glass does a handful of things—it can take videos, give you turn-by-turn directions, make phone calls, or search the Web—but it doesn't do any of them all that well. It might have succeeded while looking weird if it let you do amazing things (the forthcoming Oculus Rift virtual-reality headset looks goofy, but people will eagerly put it on). Or it might have found more fans even if it didn't do all that much—as long as it looked unobtrusive.

However, I can see how smart glasses will improve on both counts. The idea that Glass represents—allowing you to ingest digital information at a glance—remains powerful. Even though I gave up on wearing Google Glass pretty quickly, I did find it helpful in situations where I wanted to be online yet didn't want to be interrupted—while cooking or cycling, for instance. I could easily look at the list of ingredients in a recipe by tilting my head upward, or shift my eyes to check my speed on a descent. A display in your line of sight can make for a better navigational tool or real-time language-translation assistant than a smartphone.

And far more intriguing possibilities remain. A device that could sense what you were doing at a given moment and serve up relevant information into your field of view could be incredibly useful as a memory aid and productivity enhancer. Those kinds of applications are always cited by wearable-computing die-hards like Thad Starner, a Georgia Tech professor and Glass technical lead who has been making and wearing these kinds of gadgets since 1993. (See my Q&A with Starner in July/August 2013.)

Researchers inspired by these prospects—and companies that make wearable devices for niche applications—are going to keep plugging away in hopes of getting to a point where the technology blends into the glasses themselves, rather than sitting so obviously atop them. So imagine that in a few years someone comes out with smart glasses that are pretty much unnoticeable. They have a tiny display in the lenses; the electronics and battery are neatly concealed in the frame. They're operated easily with a few fairly inconspicuous touch gestures, eye movements, and, when appropriate, voice commands.

This version of the technology wouldn't automatically irk people around you. And surely that would inspire software developers to have another try at creating applications that finally deliver the information-rich lifestyle Starner calls a "killer existence."

Blending in

There are several ways the technology can be streamlined significantly.

There's no ignoring the prism-like display on the current version of Google Glass. It juts out from the frame and sits just above your eyeball. When the display is on, other people can't fail to see the bright little mirror image of what you're looking at. Even when the display is turned off, rendering the prism a clear block in front of your right eye, it's impossible to forget about. For a device like this to have a chance, it will need a display that is much more discreet.

Google

Lumiode

Innovega

Perpetua Power

One solution may be something like what's in the works at Lumiode, a startup that uses LEDs to create microdisplays. Typically, LEDs serve as the light source at the rear of a display, and the light passes through filters to form the pixels that together create images. Lumiode

eschews the filters. Instead, it uses individual LEDs as pixels by adding a layer of transistors to control how they emit light. Lumiode founder and CEO Vincent Lee says the technology could yield tiny displays that are 10 times brighter and more energy-efficient than other display technologies. That could make it easier to integrate a display into regular-looking glasses, cut down on clunky batteries, and make the glasses work better outdoors, too.

Lumiode is now focused on perfecting the process of fabricating the layer of transistors atop the LEDs without ruining the lights. Lee says the obtrusiveness of a Lumiode display that's built into a pair of smart glasses will depend on a few factors, including the optics used in the glasses. Eventually, he says, it could fit into the frame.

A more radical approach to cutting down on smart glasses' bulk may be to simply take the lens needed to magnify what's on the display out of the glasses and bring it closer to the eye. A company called Innovega is doing this by developing contact lenses with a tiny bump that serves as a microscope for content that can be streamed from the inside of a pair of glasses. The lenses do nothing when you're looking at the world around you, but when media is streamed toward your eyes from a projector or display panels built into glasses, it passes through the bump on each contact and comes into focus just in front of the eye. This offers the benefit of showing content to both eyes—and it can stay in focus as you move them.

Innovega showed off an early prototype of its technology, streaming high-definition content, at the 2014 International Consumer Electronics Show in Las Vegas. The glasses looked a lot like normal—albeit dorky—sunglasses, and chief executive Steve Willey says the company is developing a consumer contact lens. It plans to seek approval from the U.S. Food and Drug Administration in 2015.

Even if displays can be made practically invisible and much more energy-efficient, smart glasses will need battery technologies that can hold up to a full day of usage and eliminate the bulging batteries currently connected to Glass.

That probably will require a combination of breakthroughs. Software must be optimized to use power more frugally (already, the Glass team has made progress in this regard). And something like the thin, flexible, printed rechargeable batteries made by the startup Imprint

Events

EmTech Singapore
January 27–28, 2015
Marina Bay Sands, Singapore
www.emtechsingapore.com

MIT Technology Review Innovation Congress (In Conjunction with E-world)
February 11-12, 2015
Essen, Germany
http://www.e-world-essen.com/en/home/

SXSW
March 13-22, 2015
Austin, TX
http://sxsw.com/

EmTech China
March 22-23, 2015
Beijing, China
www.technologyreview.com/events

EmTech Digital
June 1-2, 2015
San Francisco, CA
www.technologyreview.com/emtech/digital/15/

BIO International Convention
June 15-18, 2015
Philadelphia, PA
http://convention.bio.org/

EmTech MIT
October 6-8, 2015
Cambridge, MA
www.emtechmit.com

Energy could be contained in the frames. These zinc-based batteries would eliminate some of the bulk typically associated with lithium-ion batteries, which require protective layers because they are sensitive to oxygen.

In addition, some sort of power harvesting could replenish the batteries throughout the day. A company called Perpetua Power is working on technology that uses body heat to produce electricity; in theory, your smart glasses could extend their battery life with tiny thermoelectric generators on places that touch your skin, such as the bridge or temple. For now, though, Perpetua's module is much too big: one by two centimeters. And each one can generate only a bit of the power you'd need to run even a fitness-tracking wristband. Perpetua's bracelet-like prototypes include eight to 10 modules.

Fashion backward

Google has tried hard to make Glass more fashionable. It formed a partnership with the world's largest eyeglass maker, Luxottica Group, whose brands include Ray-Ban and Oakley. (Intel is also working with Luxottica on a smart-glass project.) It cozied up to designer Diane von Furstenberg, who designed a Glass frame and aviator-style shades that come in hues like "shiny lagoon" and "rose gold flash."

Though it remains awkward, Glass is already miles from where it was in 2011, when it was like a scuba mask with a phone and cables attached to it.

Speaking on the sidelines of a Google-hosted design conference in San Francisco in November, Isabelle Olsson, the lead designer for Glass, said that while Google is always trying to make Glass as sleek as possible, getting people to wear a head-up display comes down to giving them cool frames and colors to choose from. She said the prospect of having more fashionable options "sounds kind of banal in a way" but is even more important than miniaturizing the technology.

"If you can pick the frame that you would normally pick and that you're normally comfortable with, it's going to look more like you," said Olsson, who wore a matte black Glass during our conversation.

I didn't expect Olsson to speak ill of Glass; she works for Google, after all, and as is true for a number of people at the company, Glass is her baby. She has managed to bring it miles from where it was when she started at Google in 2011: a prototype she described as a scuba mask with a phone attached to it and cables running to a backpack. But it's wrong to say that stylish frames matter terribly much when it comes to luring more users. It's a reminder that Google got it all backwards: after failing to give people very good reasons to wear computers on their faces, it failed to see that the devices could not possibly appeal to most people. Stylish frames can't fix that; they will make a difference only after the technology dissolves into them.

I agreed with Olsson on one big point: it's a numbers game. The more people out there who are wearing these things, the more normal it will seem, she reasons. Indeed, even regular glasses, which have been around in various forms for over 700 years, didn't become fashionable until the last century.

The difference, though, is that glasses perform a valuable function. When a pair of smart glasses do too, their sense of style might actually matter.

Rachel Metz, MIT Technology Review's *senior editor for mobile technology, wrote about anonymity apps in the November/December issue.*

PROFESSIONAL EDUCATION

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

YOUR DOOR TO MIT EXPERTISE & KNOWLEDGE

TRAINING & EDUCATION FOR PROFESSIONALS

Come to MIT for a Week

SHORT PROGRAMS

Register for a 2–5 day intensive course and gain critical knowledge to help advance your career and impact your company's success. Earn CEUs and a Certificate of Completion.

Each year approximately 40 courses are offered in a variety of subject areas (partial listing below):

- Biotechnology/ Pharmaceutical
- Crisis Management
- Data Modeling & Analysis
- Design, Analysis, & Manufacturing
- Energy/ Transportation
- Imaging
- Information & Communication Technologies
- Innovation
- Leadership
- Radar
- Robotics
- Sustainability
- Systems Engineering
- Tribology

Come to MIT for a Semester

ADVANCED STUDY PROGRAM

Enroll in MIT courses through this non-matriculating, non-degree program. Participate on a full or part-time basis for one or more semesters.

As an Advanced Study Program participant you can:

- Advance your knowledge in the latest technologies and cutting edge research
- Choose from over 2,000 MIT undergraduate and graduate courses
- Earn grades, MIT credit, and a Certificate of Completion

Bring MIT to You

ONLINE X PROGRAMS

Interact with professionals from around the world without disrupting your work-life balance. Online courses designed to advance your career at your own pace with a flexible schedule that meets the needs of a global workforce.

Tackling the Challenges of Big Data
6 week online course announced for Fall 2014 & Spring 2015. **HTTP://MITPROFESSIONALX.EDX.ORG**

INTERNATIONAL PROGRAMS

Schedule regionally relevant MIT short courses in a global location near you today. MIT Professional Education will work with you to match your regional needs with relevant subject areas in the Short Programs portfolio.

CUSTOM PROGRAMS

Enhance your organization's capabilities and expertise through customized programs tailored to meet your specific corporate education needs and strategic goals.

To learn more about what MIT Professional Education can offer you and your company, visit us today at **HTTP://PROFESSIONALEDUCATION.MIT.EDU/TECHREVIEW** or email us at **PROFESSIONALEDUCATION@MIT.EDU.**

The Boundary Dam power station.

A Coal Plant That Buries Its Greenhouse Gases

The first commercial power plant to use carbon capture and sequestration shows the potential of a crucial technology.

By Peter Fairley
Photographs by Jenn Ackerman and Tim Gruber

BOUNDARY DAM, A POWER PLANT IN ESTEVAN, SASKATCHEWAN, is the first commercial coal-fired plant to capture carbon dioxide from its emissions, compress the gas, and bury it underground. The plant demonstrates that so-called carbon capture and storage (CCS) can work at a large scale—a crucial achievement given that CCS could play a significant role worldwide in reducing the greenhouse-gas emissions that contribute to climate change.

Right now only two other CCS power-plant projects are under construction, both of them in the United States. That's because CCS carries a hefty price tag: SaskPower invested $1 billion to equip one of the four generators at its Boundary Dam site for carbon capture. What's more, the process reduces the 160-megawatt plant's electricity output by about 20 percent, meaning it may cost SaskPower more per kilowatt-hour to run CCS than the 12 cents it gets for selling the electricity.

1

2

1 Coal from a nearby strip mine is pulverized for burning.

2 Ductwork (bottom left) carries flue gas to an adjacent carbon capture facility. There, it bubbles through a 52-meter-high column filled with a solution containing chemicals called amines, which absorb 90 percent of the carbon dioxide. The rest vents from the facility.

3 The carbon-rich amine solution (RAC) is piped to a heater that removes CO_2; the lean solution (LAC) is piped back to repeat the process.

3

4 Cooling water travels through the green pipes into a chamber that helps cool carbon dioxide as part of a compression process.

4

5 The carbon dioxide is turned into a supercritical liquid inside this 15-megawatt compressor. Approximately 3,000 tons of carbon dioxide is captured and compressed every day.

5

6 A gauge at the CCS plant indicates the flow rate of carbon dioxide.

7 Most of the carbon dioxide travels 65 kilometers to an oilfield (shown here), where it's injected to help boost production. But some is injected at SaskPower's site.

8 At the SaskPower site, a wellhead delivers carbon dioxide to its resting place, a saline aquifer 3.4 kilometers underground.

SaskPower makes up for this in large part by selling much of the captured carbon dioxide to the Calgary-based oil producer Cenovus, which uses it to boost output from its maturing oil wells nearby.

CCS should get cheaper over time. The Intergovernmental Panel on Climate Change, the panel of climate scientists convened by the United Nations, projects that technology upgrades and economies of scale should reduce the price of adding CCS to coal plants to just one-third of what SaskPower spent at Boundary Dam. If so, CCS-equipped coal plants could deliver electricity more cheaply than some other low-carbon sources, including offshore wind power and large solar farms.

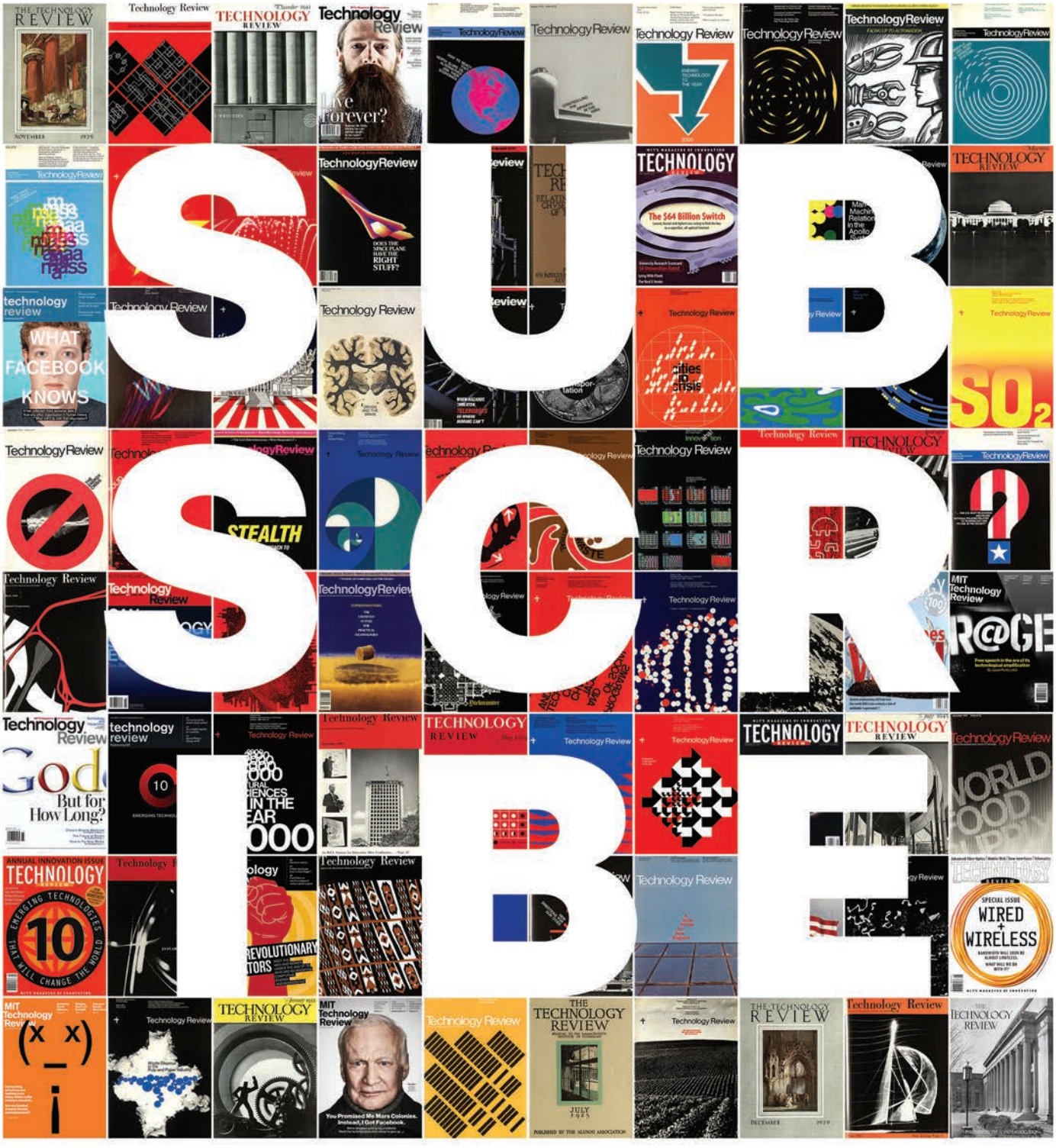
SaskPower says that with the lessons it's learned so far, it could now build a similar CCS project for $200 million less, and that it may soon go forward with CCS at two other aging coal generators at Boundary Dam. It also hopes to help other power companies develop expertise in the technology.

Still, coal plants around the world generally have little incentive to follow suit. In SaskPower's case, Canadian regulations helped force the company's hand; that fact, plus the availability of a local buyer for carbon dioxide, makes SaskPower's effort somewhat unusual. What might be needed elsewhere is a way for utilities to pass along CCS costs to customers, just as many do now to pay for renewable energy sources. Another approach would be to tax carbon dioxide emissions, creating an incentive to bury the gas instead.

The technology must also be proven to work over the long term. SaskPower buries some gas in a saline aquifer on its site. To make sure it stays put, the company has installed aboveground gas sensors plus a seismic sensing array to track subsurface movement.

The United Nations climate panel says similar technology must be installed at all 7,000 existing coal power plants worldwide by 2050 to keep warming below 2 °C, a widely cited threshold for avoiding severe climate change. Meanwhile, new coal plants are still being built, especially in China and India. With coal plants expected to provide one-quarter of the world's energy supply in 2040, SaskPower could help test the feasibility and safety of burying billions of tons of carbon dioxide emissions.

IMAGE 7 COURTESY OF CENOVUS ENERGY



MIT Technology Review

Subscribe to *MIT Technology Review*
and explore the technologies that matter.

technologyreview.com/subscribe

45 Years Ago

Teaching the Many, Rather than the Few

Four decades before the MOOC, a 1970 essay anticipates the potential boon of an education by computer.

"One of my greatest frustrations as a teacher has been my inability to meet simultaneously the needs of all my students. Students differ greatly from one another, not only in their intellectual capabilities: some proceed from the general to the specific; others from the specific to the general; some refuse to pay attention to details before they have acquired an overall view, while others cannot see the forest before having examined each tree. Individual instruction is the ideal answer; however, the necessary number of qualified teachers is just not available. Computers, if properly used, may provide a way out.

Computer-aided instruction is often misleadingly described as 'replacing teachers with computers.' This interpretation implies mechanizing, rather than personalizing, education. Instead, we should strive for an interaction between teacher and student through the medium of a computer system. The goal is to make it possible for a teacher to provide individual guidance to many students instead of a few.

We may envision computer-aided instruction operating as follows: Each student uses the material stored in the computer system, learning and answering questions, under control of a program appropriate to his needs. The teacher monitors progress, and modifies the control program for each student as needed. If a student encounters difficulties, the teacher is called to give personal assistance through his own computer terminal.

This opportunity hinges on bringing the power of computers to the service of the individual, a significant departure from the attitudes and trends that prevail today."

Excerpted from "Computers in Human Society: For Good or Ill?" by MIT professor Robert M. Fano, from the March 1970 Technology Review.

MIT Technology Review (ISSN 1099-274X), January/February 2015 Issue, Reg. U.S. Patent Office, is published bimonthly by MIT Technology Review, 1 Main St. Suite 13, Cambridge, MA 02142-1517. Periodicals postage paid at Boston, MA, and additional mailing offices. Postmaster: send address changes to MIT Technology Review, Subscriber Services, PO Box 5001, Big Sandy, TX 75755, or via the Internet at www.technologyreview.com/customerservice. Basic subscription rates: $41.94 per year within the United States; in all other countries, US$54. Publication Mail Agreement Number 40621028. Send undeliverable Canadian copies to PO Box 1051 Fort Erie, ON L2A 6C7. Printed in U.S.A. Audited by the Alliance for Audited Media

Bose is pleased to offer special savings to students, alumni, employees and retirees of M.I.T.

Call to learn more.

Receive savings on most Bose® products, including music systems, surround sound systems, headphones and solutions for today's most popular portable music devices. Enjoy Bose sound at home and work.

Speakers

SoundLink® Mini *Bluetooth*® speaker with soft cover and travel bag

Full, natural sound from an ultra-compact speaker that fits in the palm of your hand. Travel bag available in Gray. Colored covers available: Blue, Red, Mint, Gray and Pink.

Headphones

QuietComfort® 20 Acoustic Noise Cancelling® headphones

Use them to shut out the world and focus on your music. Or, choose Aware mode to hear what's around you.

NEW

SoundTrue™ audio headphones

Bose sound quality that fits your music – and your style. In a variety of colors. With inline mic for phone calls.

Savings only available by phone: 1-888-501-8566

Please direct all inquiries to the "M.I.T. Savings Program."
View products online at Bose.com

Remember to ask about recognition and incentive gifts to motivate employees and business partners.

BOSE
Better sound through research

Secure. Scalable. Energy Efficient.

Cars communicating with highways to avoid accidents and traffic congestion. Home hubs talking to the smart grid to reduce energy consumption. Medical monitoring from across town. The billions of intelligent connections that make our world smarter, greener and safer. Freescale's unique product portfolio makes us the only company in the world to provide secure, embedded processing solutions from the edge node through the gateway to the cloud. For more information, visit **freescale.com/IoT.**

freescale™